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Sugiura

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(54) **INTERNAL COMBUSTION ENGINE AND VEHICLE INCORPORATING SAME**

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(73) Assignee: **Honda Motor Co., Ltd.**, Tokyo (JP)

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F01L 1/34 (2006.01)

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(58) **Field of Classification Search** ..... 123/90.16, 123/90.27, 90.31, 90.44, 90.6, 193.5, 195 C, 123/193.3, 198 F
See application file for complete search history.

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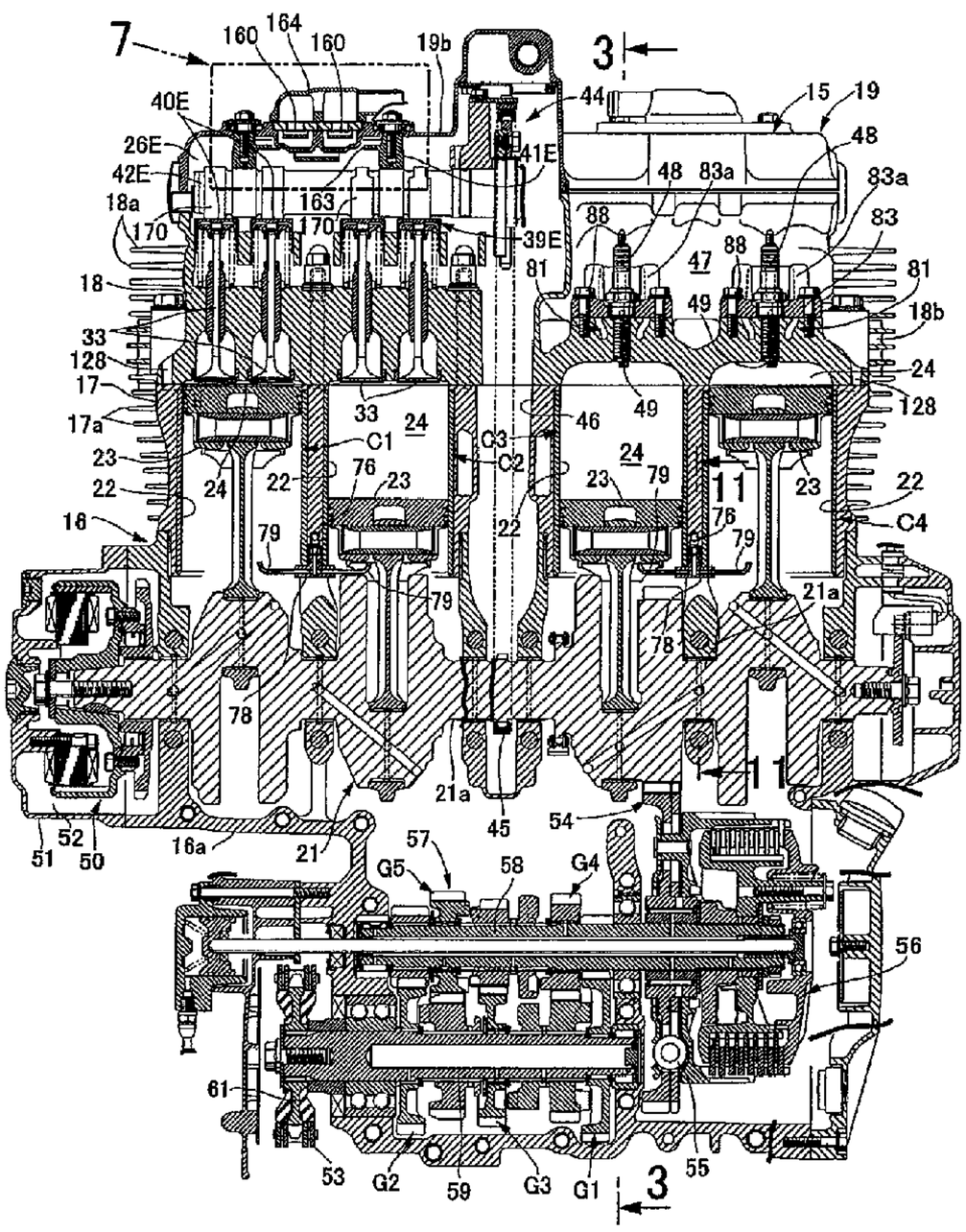
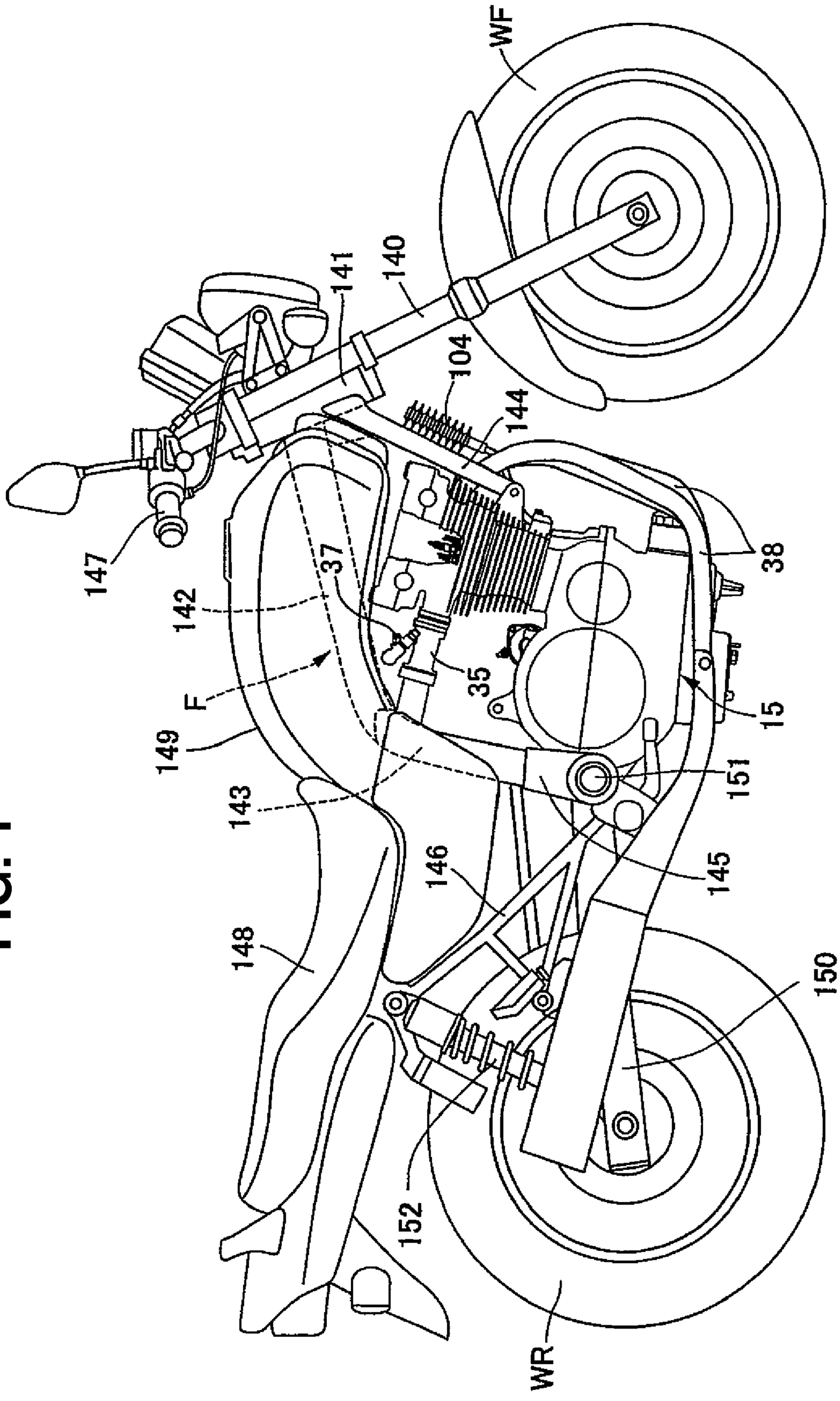
(74) *Attorney, Agent, or Firm* — Carrier Blackman & Associates, P.C.; William D. Blackman; Joseph P. Carrier

(57) **ABSTRACT**

An internal combustion engine includes a main enlarged member extended towards a camshaft for forming reed valve chambers. The main enlarged member is integrally provided on a head cover of the engine at a location at which reed valves for controlling supply of secondary air to an exhaust system are disposed. The main enlarged member is extended towards the camshaft for increasing volume of the reed valve chambers while avoiding the increase in size of the head cover. A recessed portion is provided on a cam cap fastened to a cylinder head of the engine. A portion of the main enlarged member is inserted into the recessed portion such that cam cap cooperates with the cylinder head for rotatably supporting the camshaft.

20 Claims, 16 Drawing Sheets

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141
140
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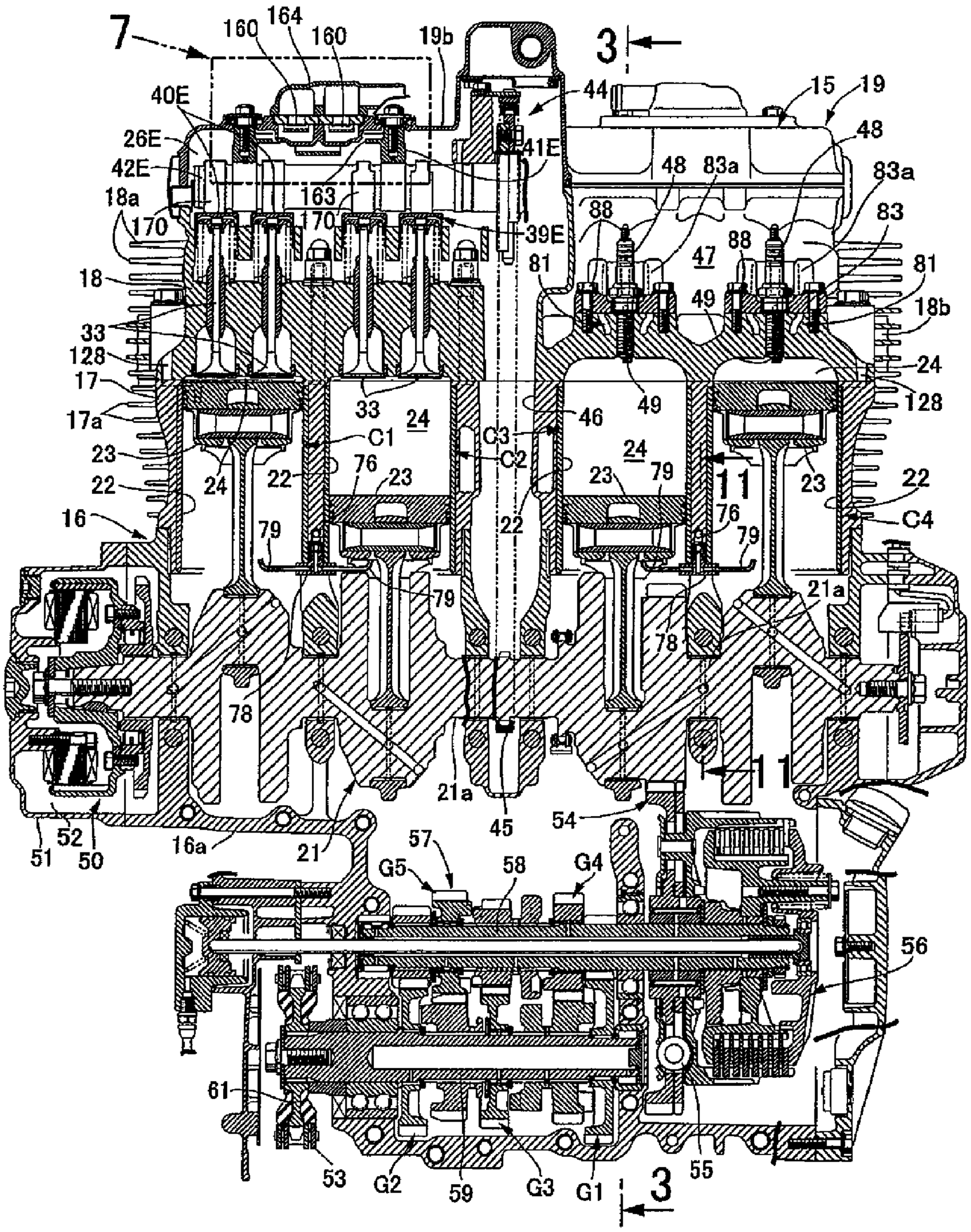
WR

FIG. 1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164
160
19b
3
40E
44
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19
26E
41E
48
42E
48
83a
83a
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163
88
83
170
170
39E
88
81
47
81
18
49
18b
33
128
24
17
49
128
17a
33
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46
C1
C3
24
23
C2
76
22
24
22
23
23
79
11
23
22
22
76
C4
16
79
79
79
21a
78
78
21a
11
45
54
52
51
50
16a
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G5
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G4
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61
53
G2
59
G3
G1
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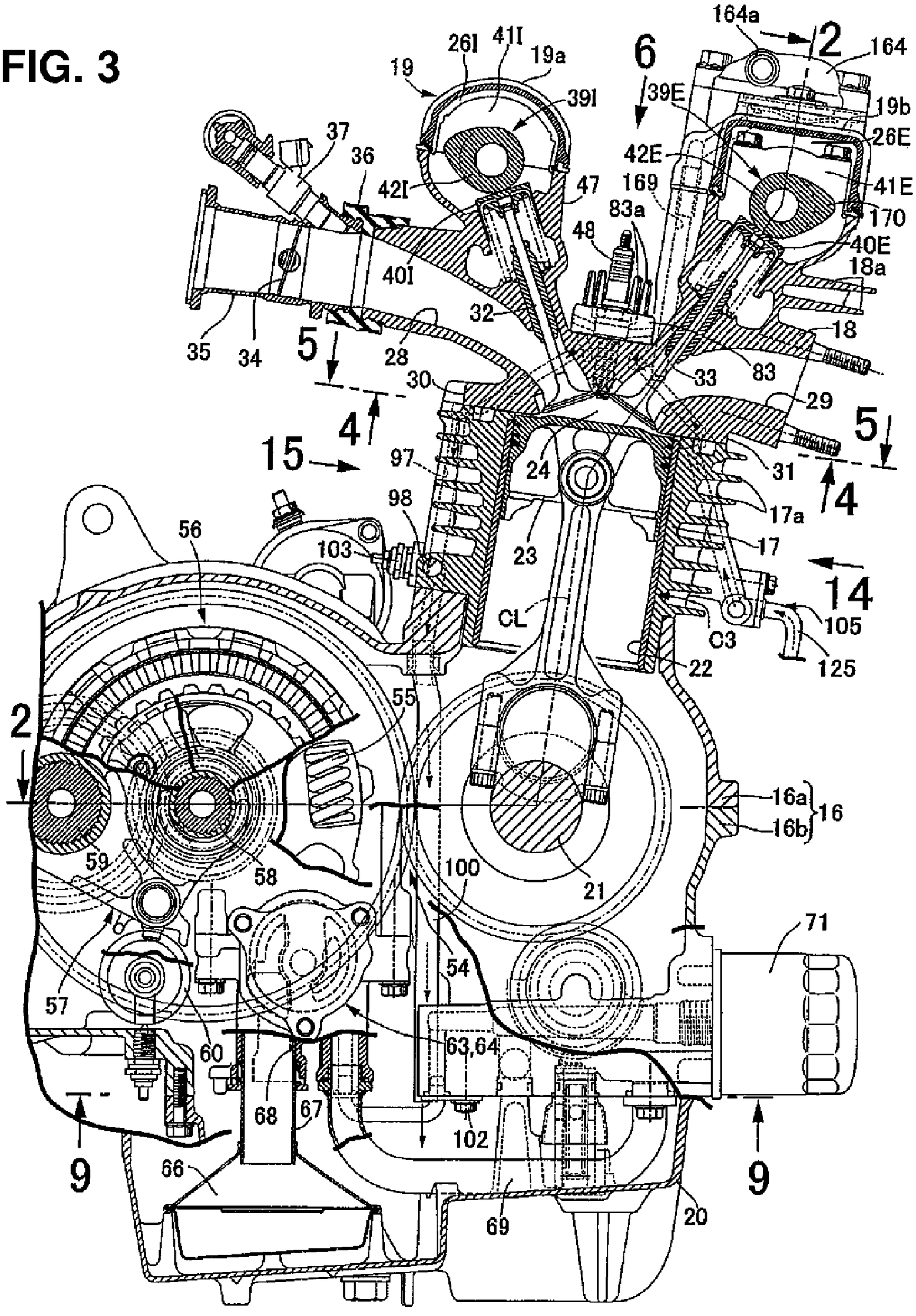
FIG. 2

FIG. 3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2
164
6
26I
41I
19a
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39I
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19b
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42I
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41E
83a
170
48
40E
18a
40I
32
18
35
34
5
28
33
83
30
29
5
4
15
97
24
31
4
98
17a
56
103
23
17
14
CL
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C3
125
22
55
2
16a
16
16b
59
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100
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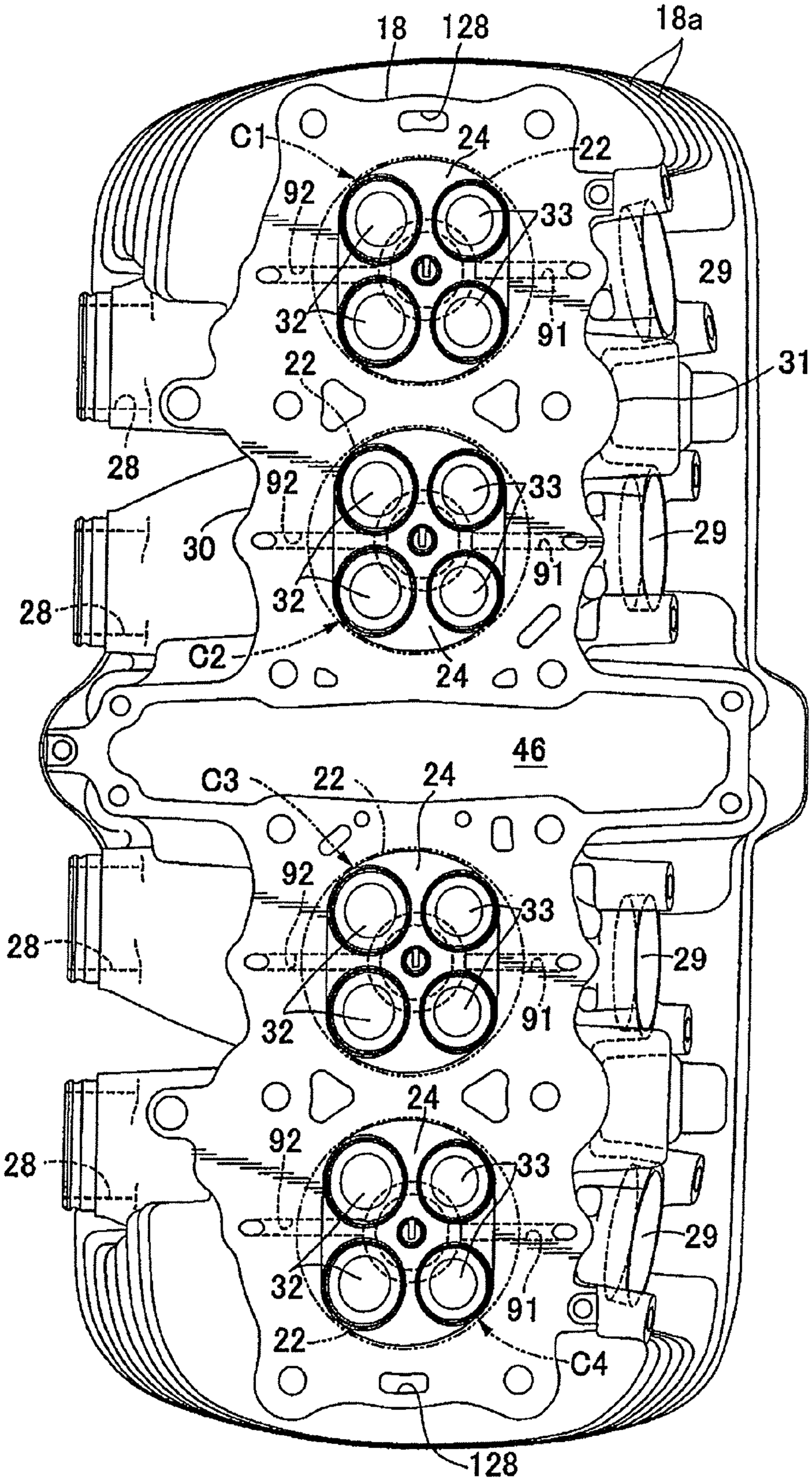
9

FIG. 4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18a
C1
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C2
24
46
C3
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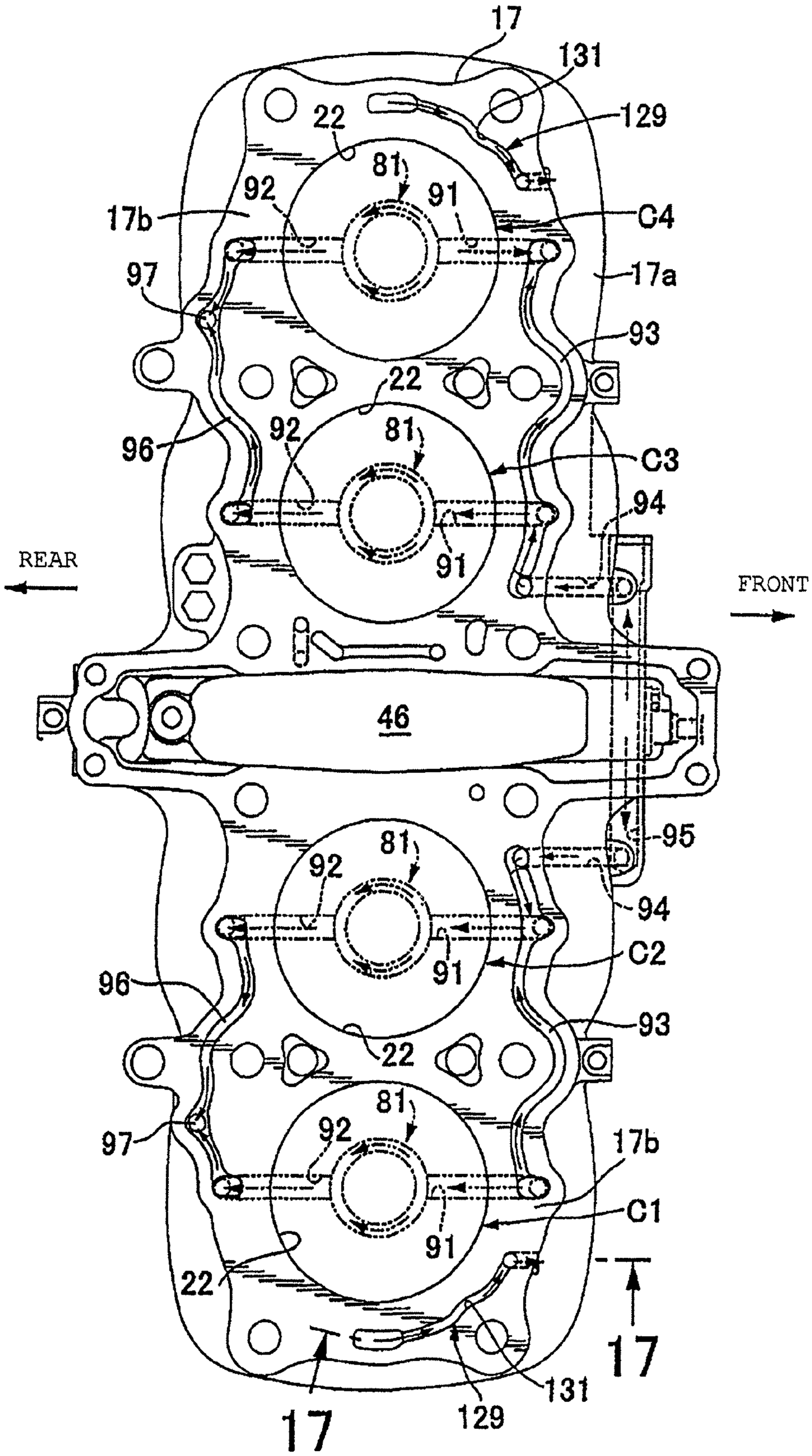
C4
128

FIG. 5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94
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FRONT
91
46
95
81
92
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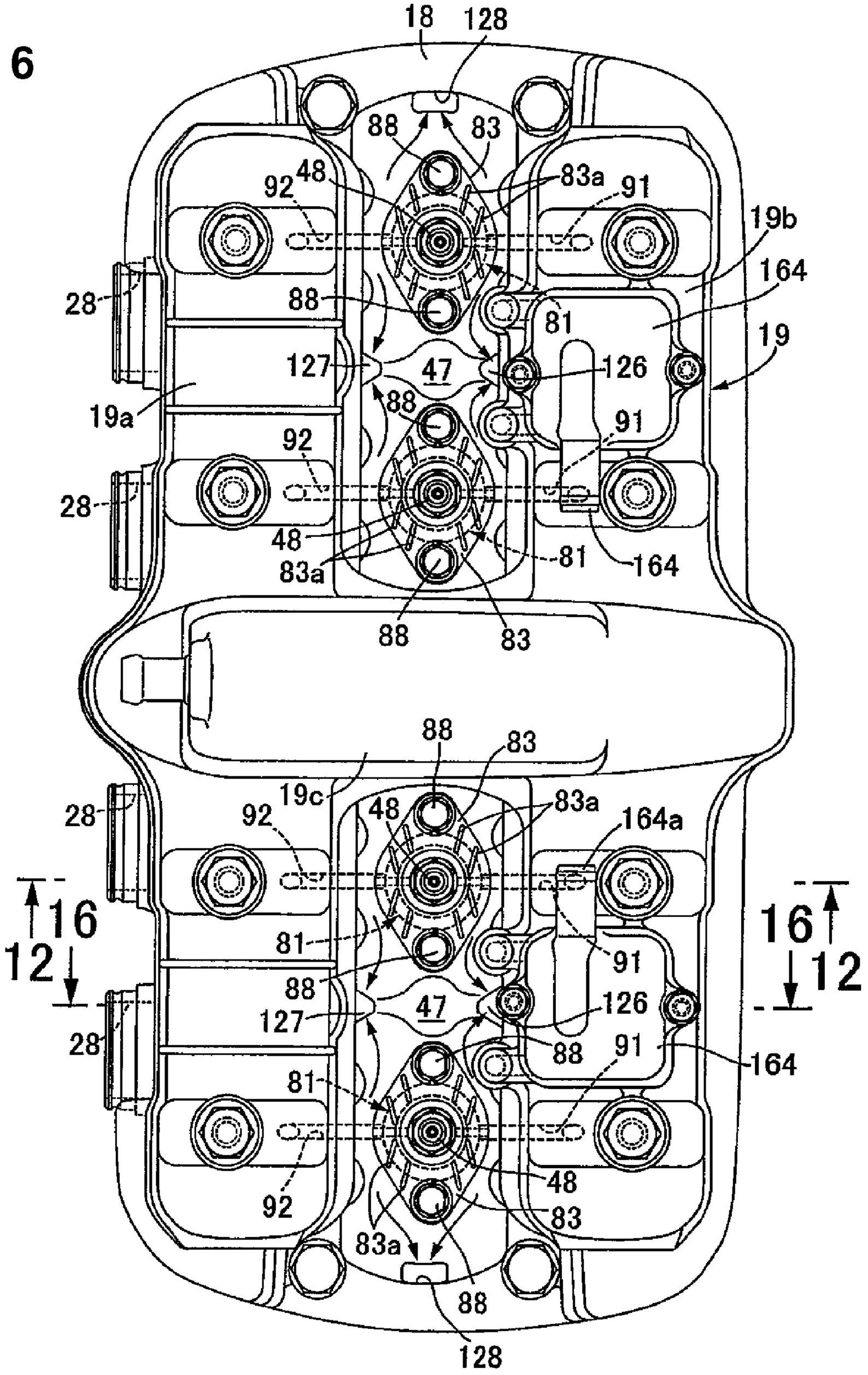
FIG. 6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83a
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19c
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83a
164a
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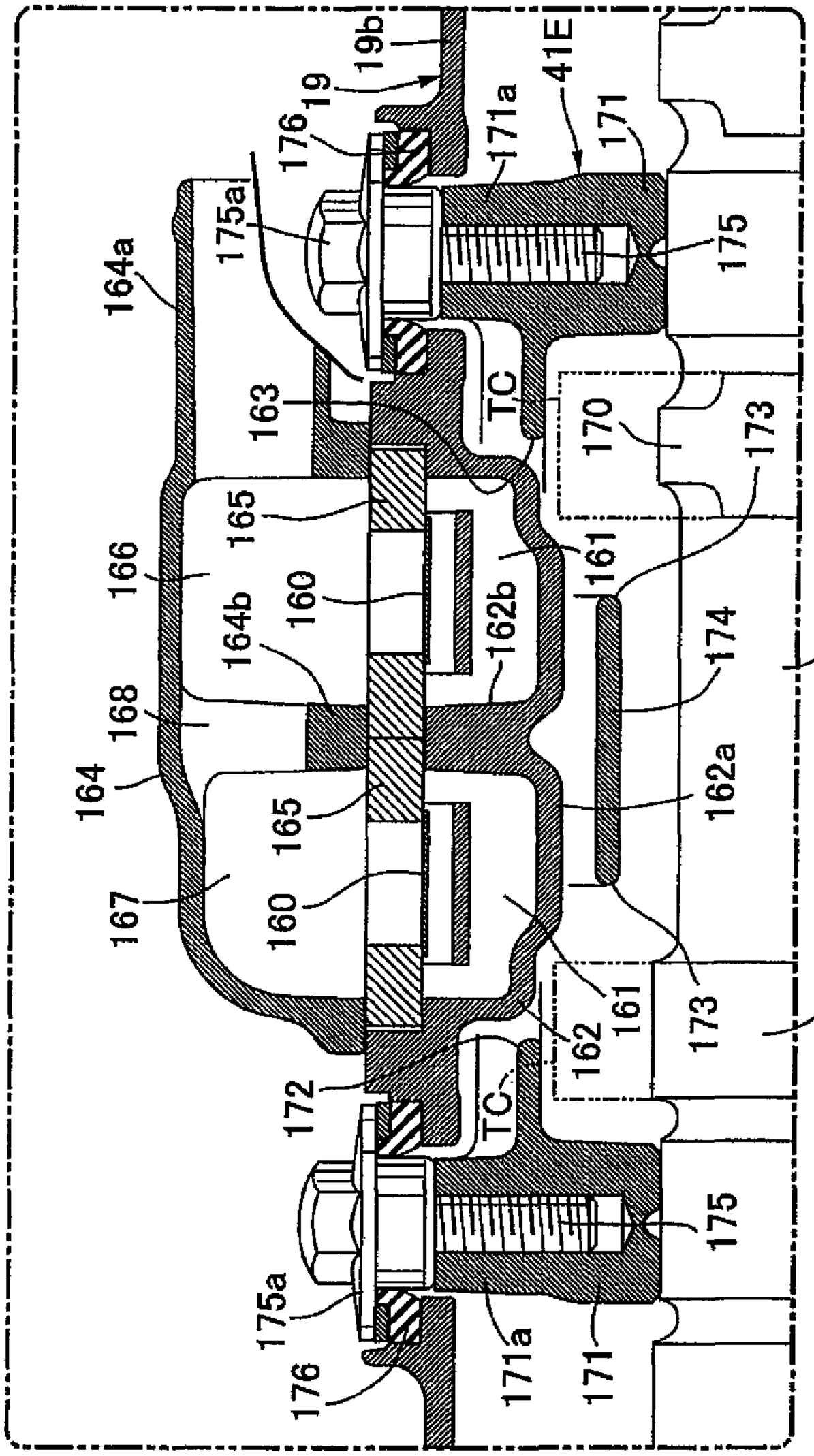
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41E
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171a
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175a
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164a
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TC
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174
42E
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TC
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175a
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171a
171

FIG. 7

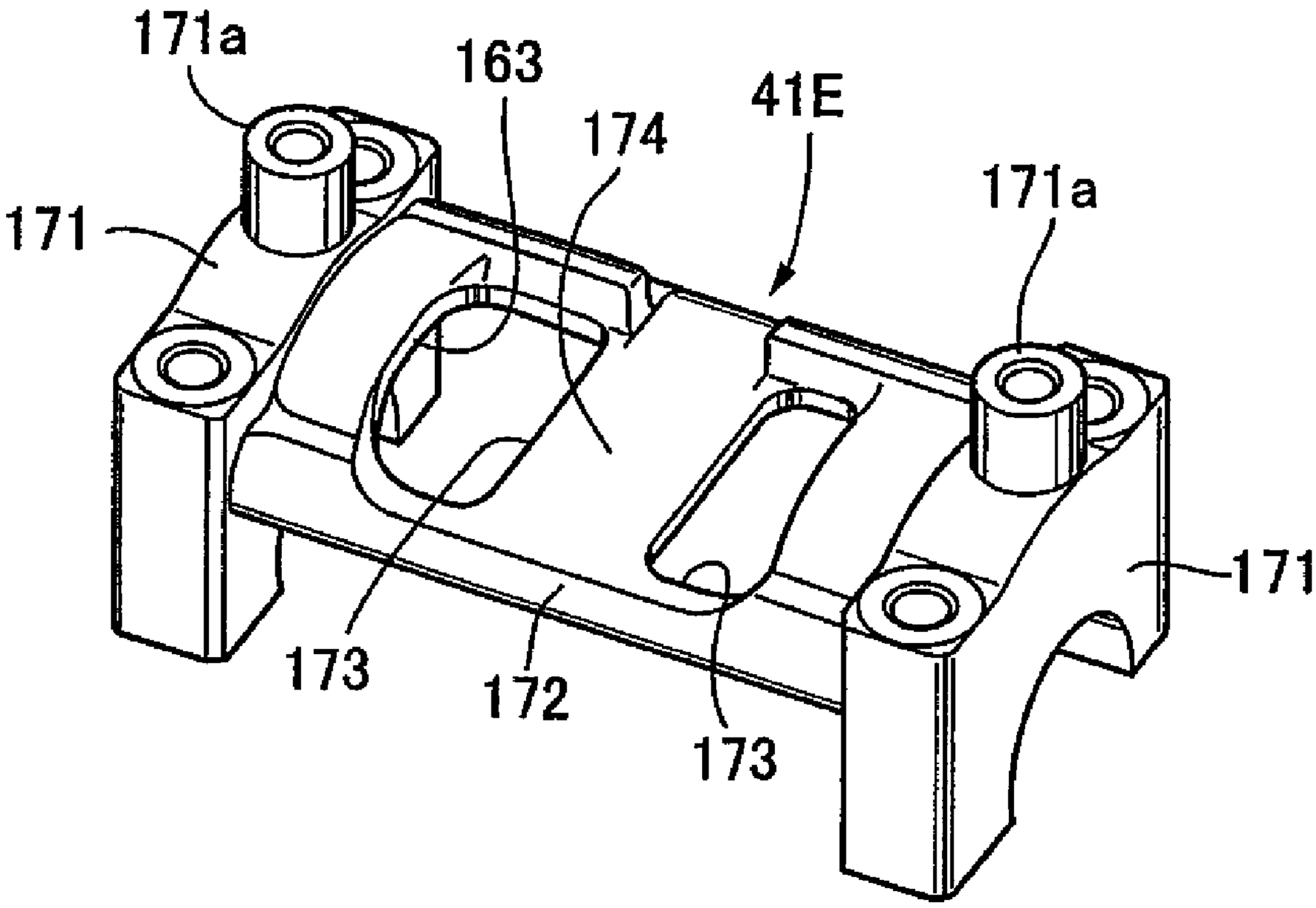

FIG. 8

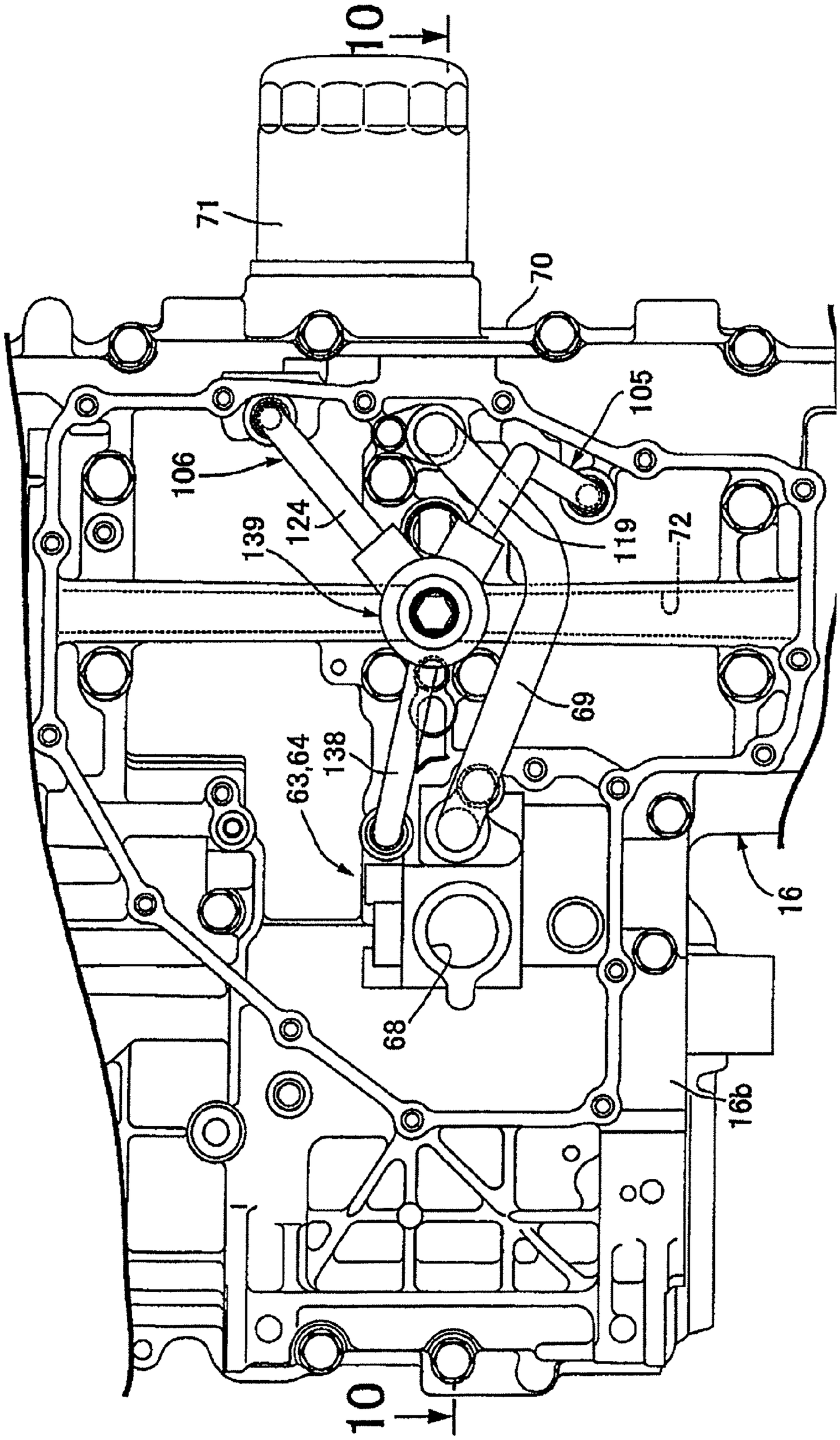

FIG. 9

FIG. 10

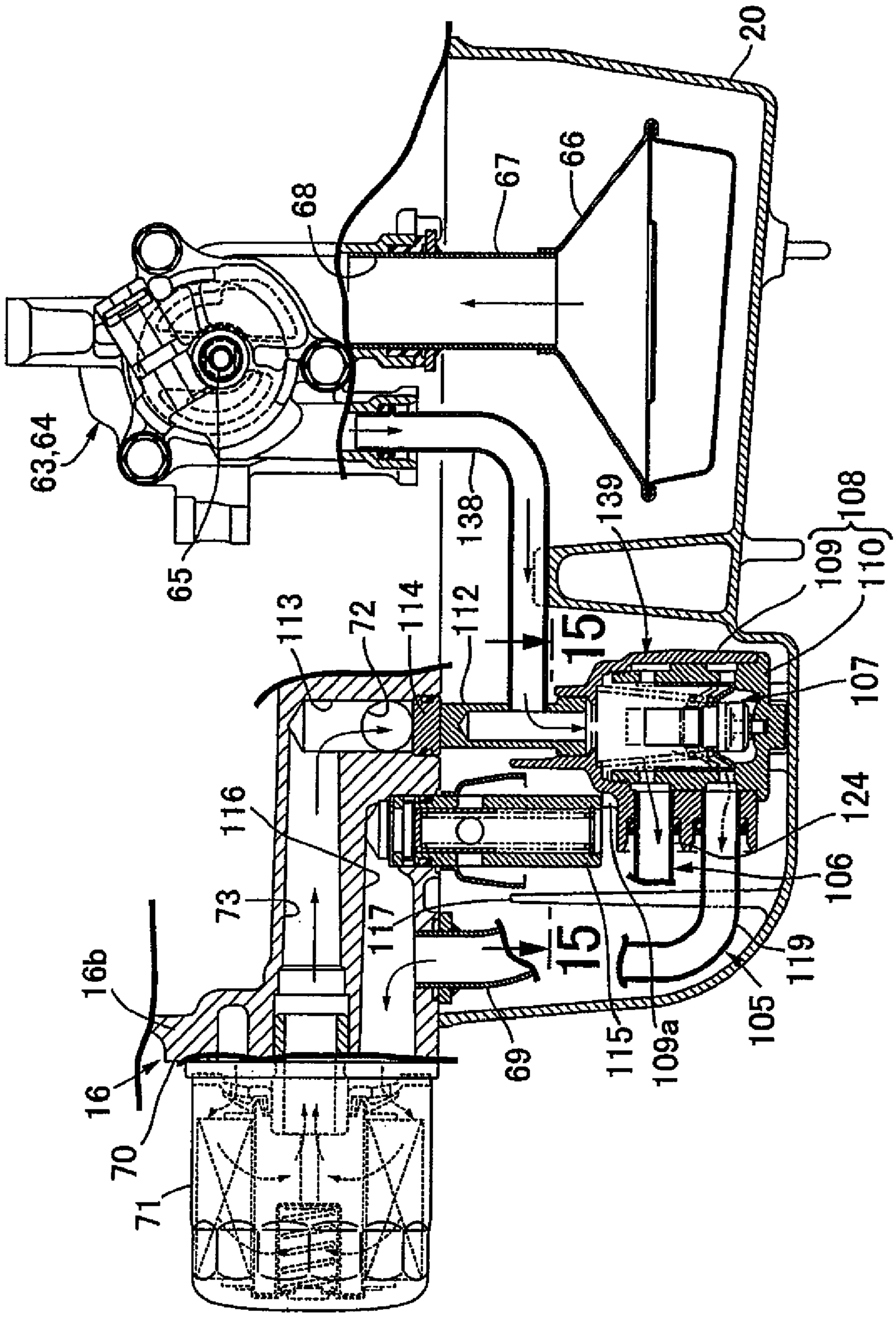
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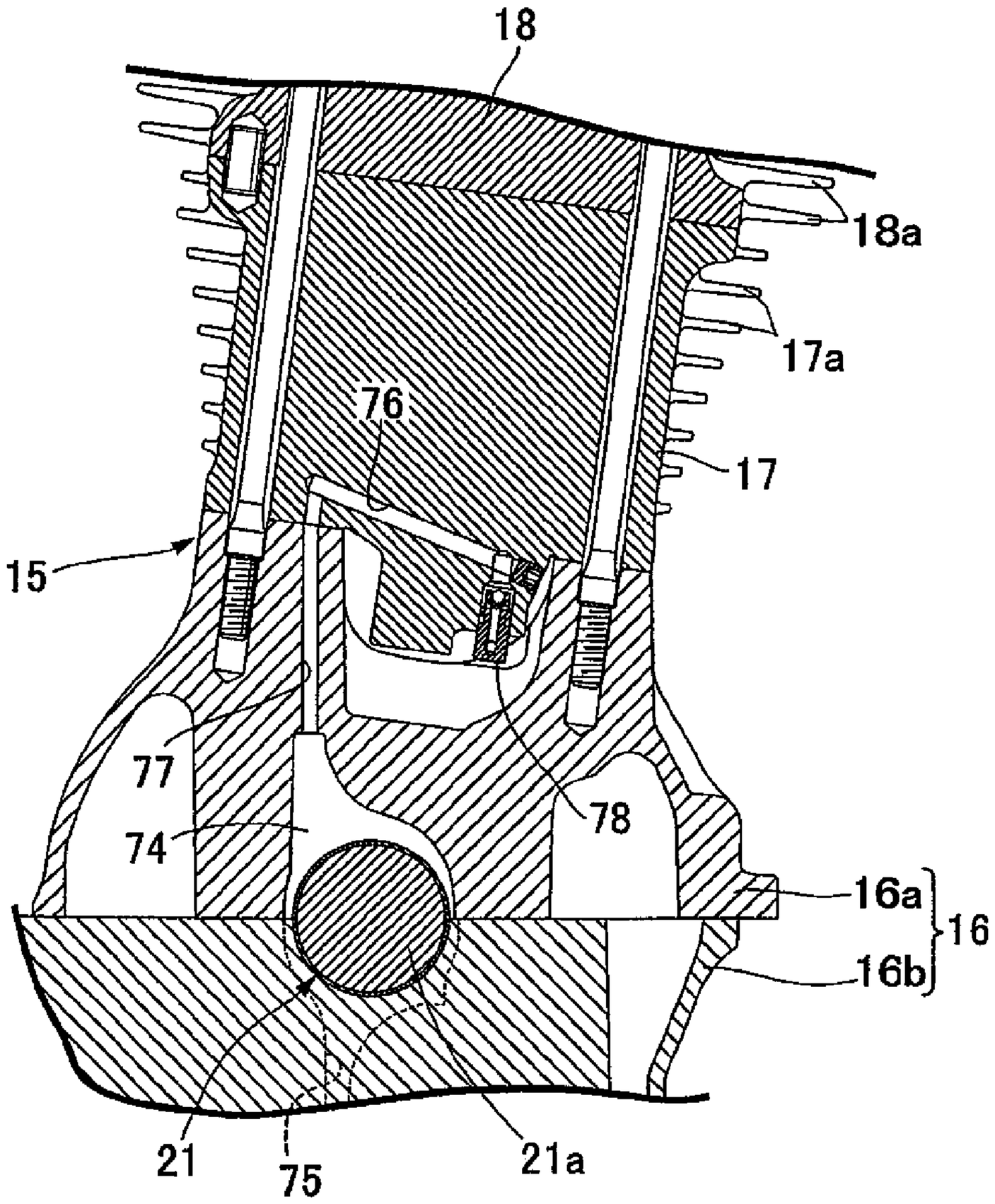
FIG. 11



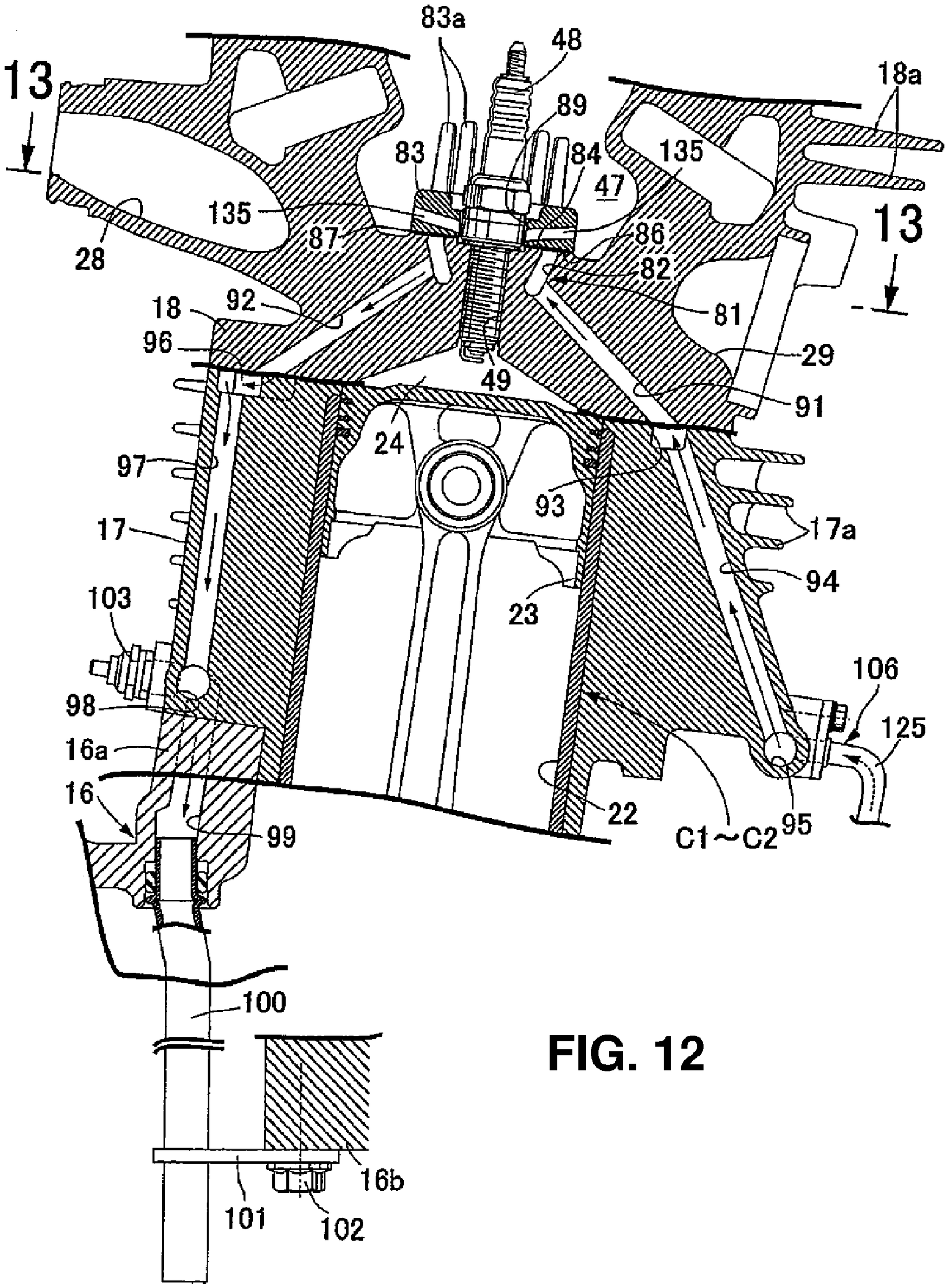

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FIG. 12

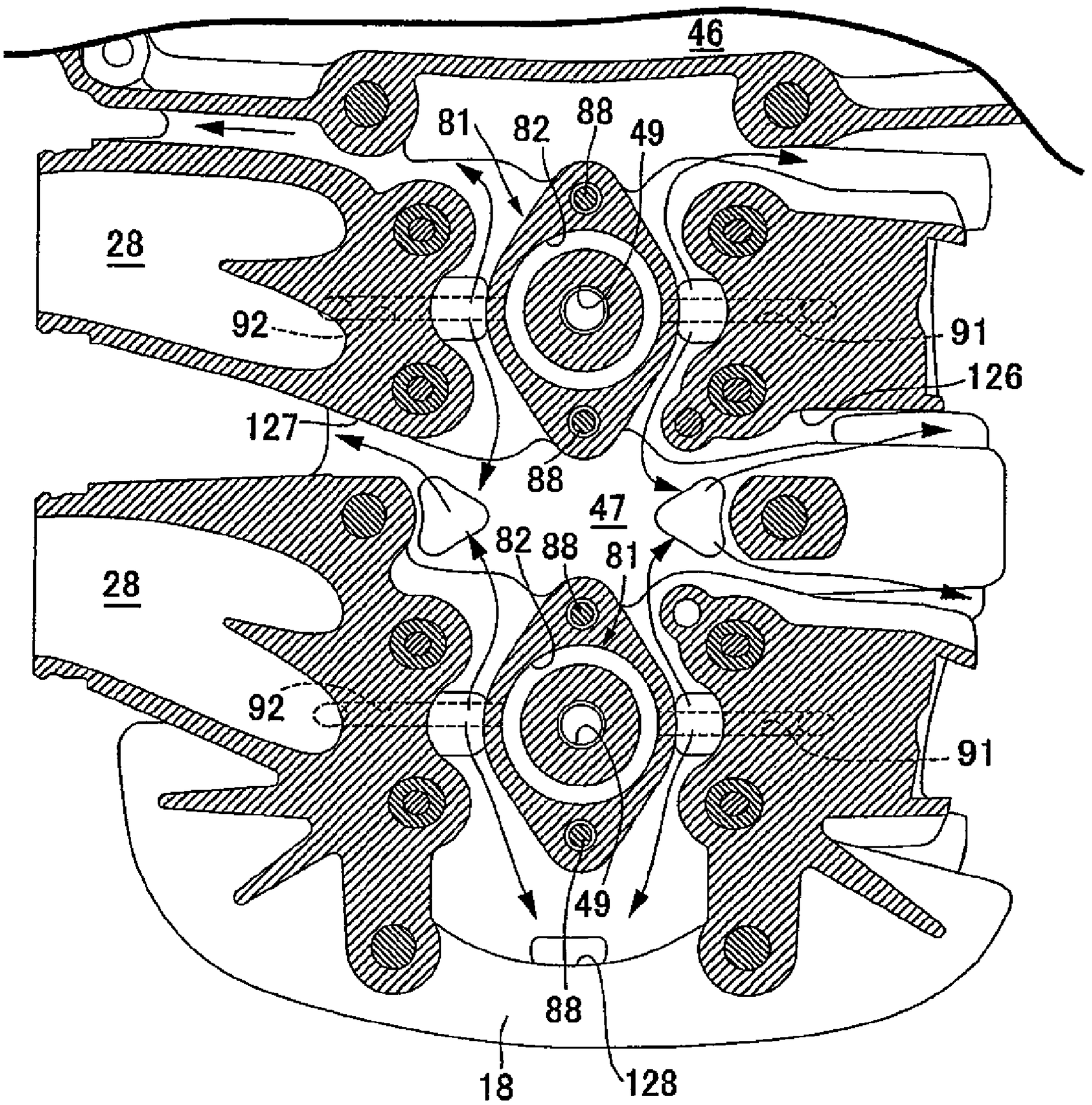

FIG. 13

FIG. 14

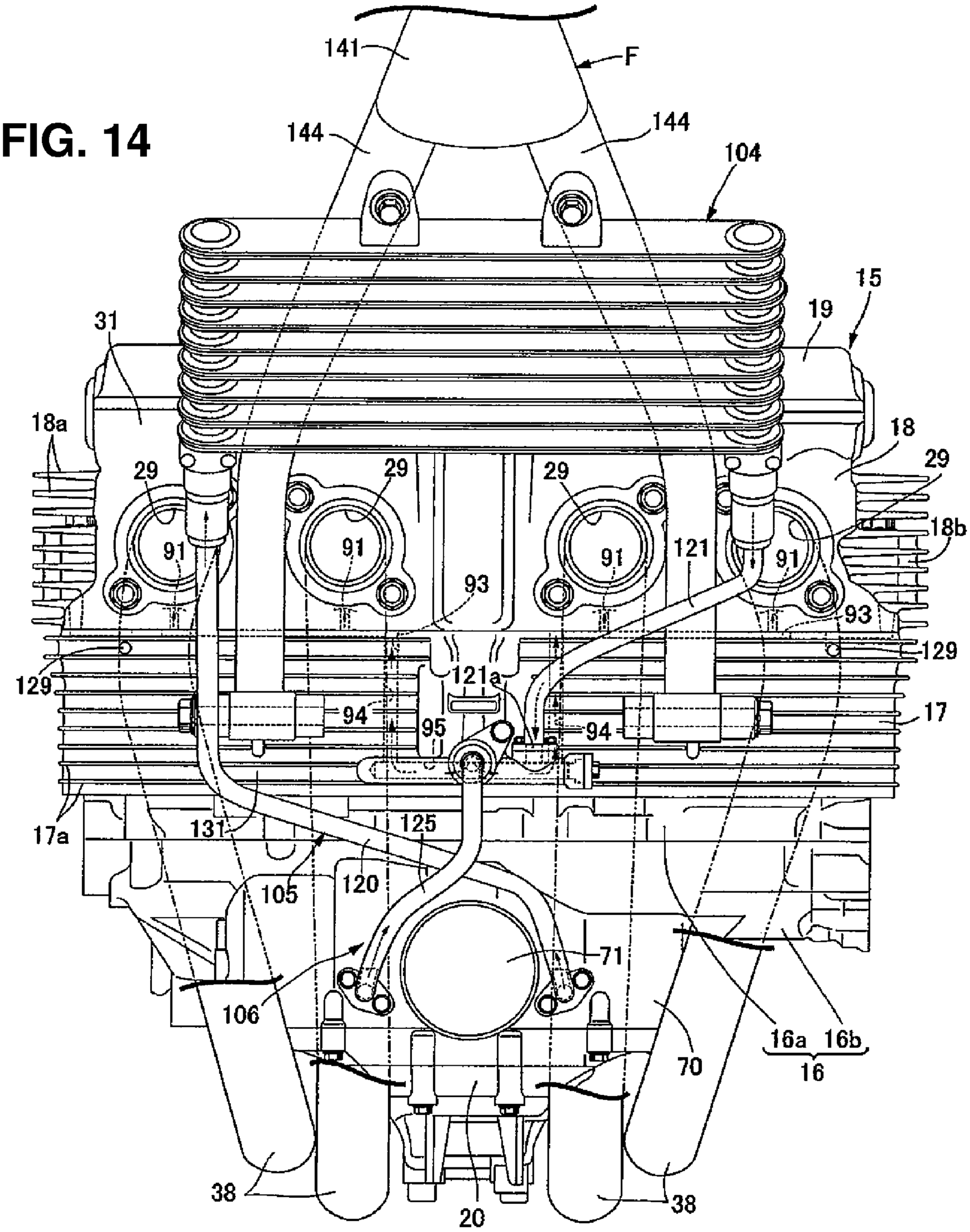
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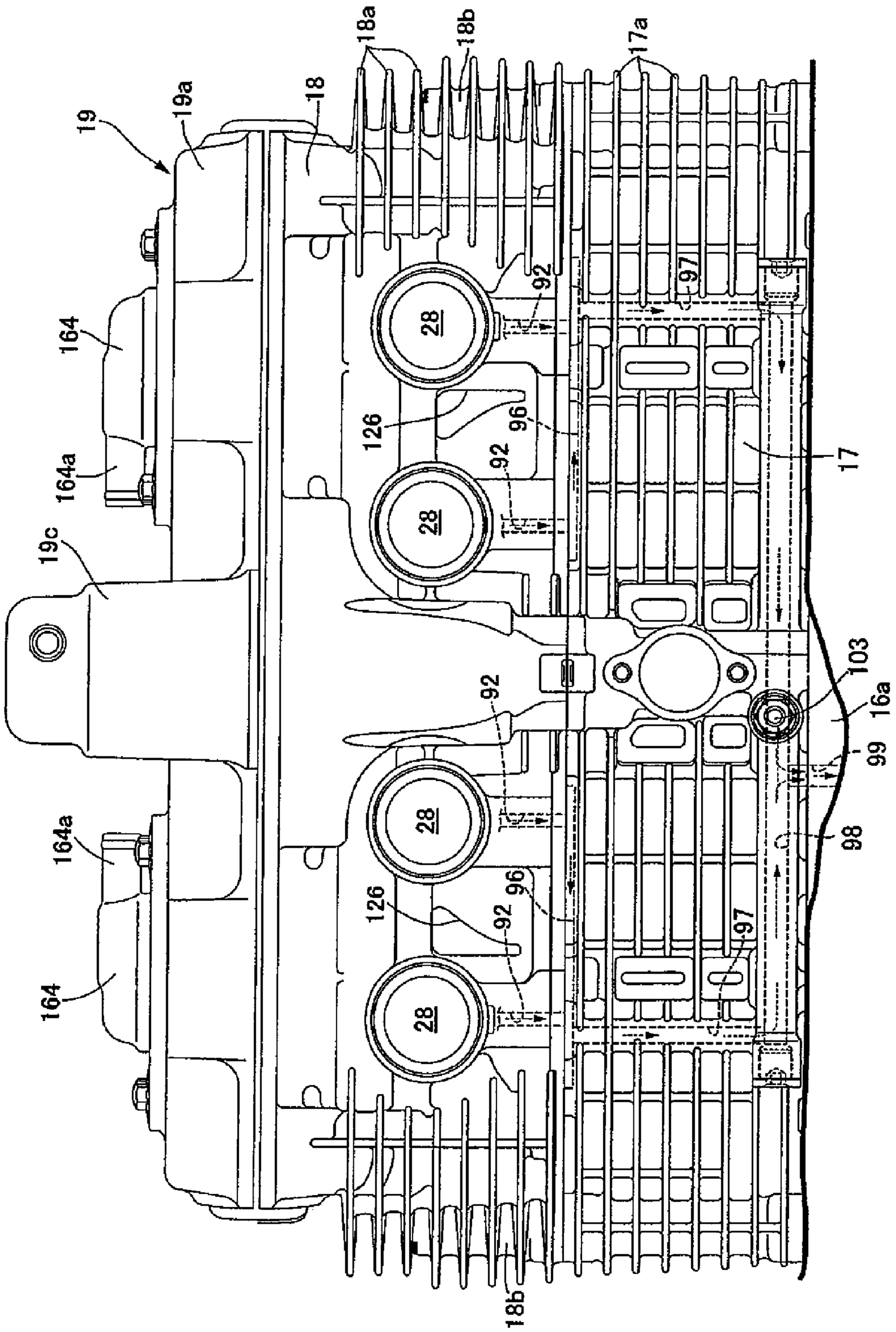
FIG. 15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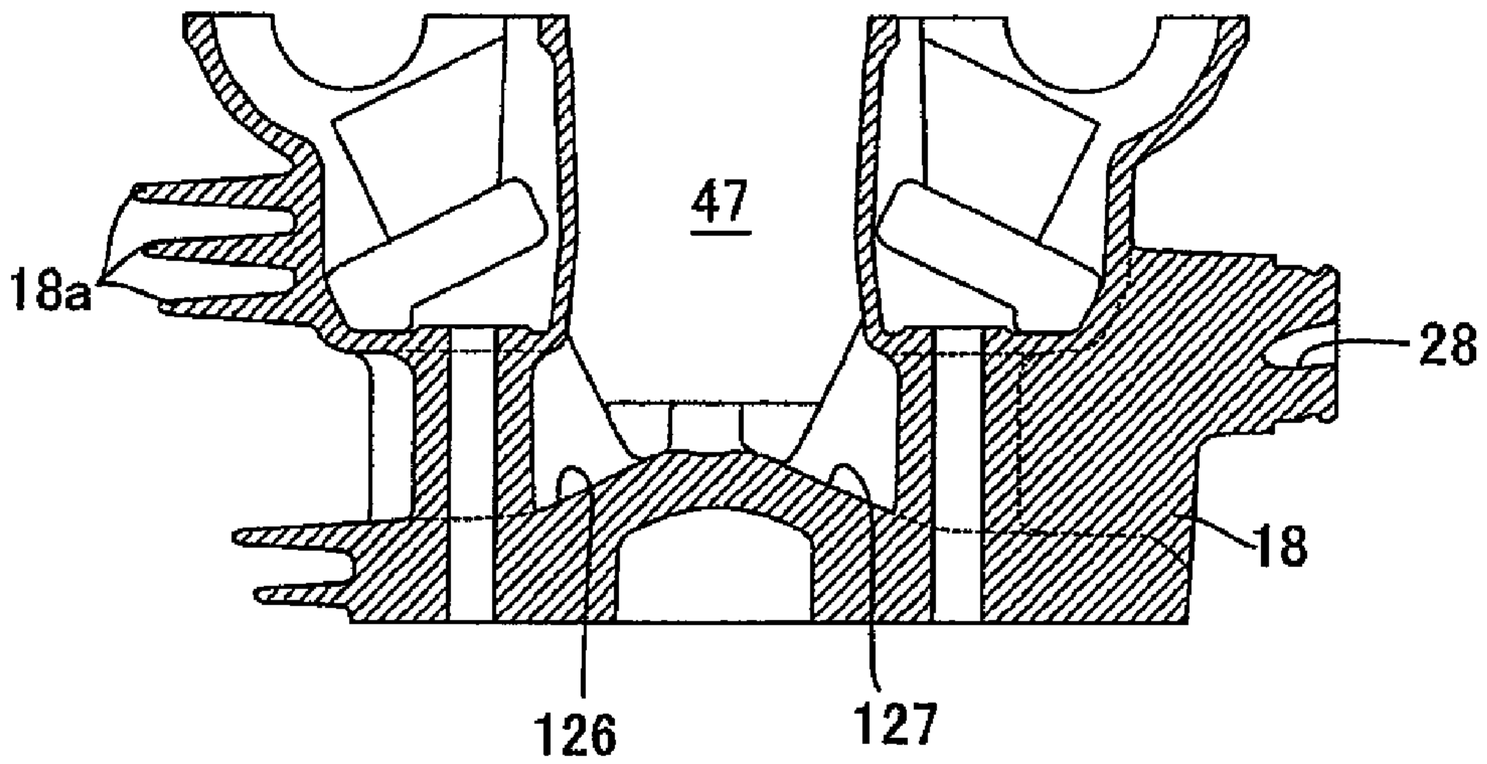

FIG. 16

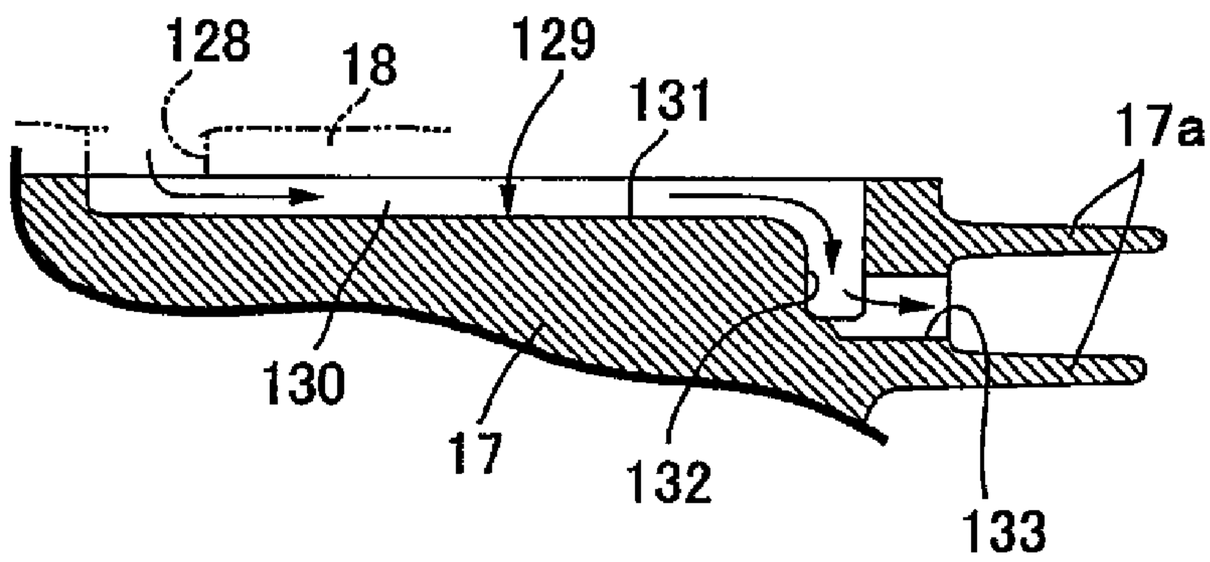

FIG. 17

INTERNAL COMBUSTION ENGINE AND VEHICLE INCORPORATING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention claims priority under 35 USC 119 based on Japanese patent application No. 2009-055595, filed on Mar. 9, 2009. The entire subject matter of this priority document, including specification claims and drawings thereof, is incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an internal combustion engine, and to a vehicle incorporating the same. More particularly, the present invention relates to an internal combustion engine having a reed valve for controlling supply of secondary air to an exhaust system, disposed on a head cover which cooperates with a cylinder head to form a valve motion chamber for accommodating a valve motion apparatus including a camshaft and a main enlarged member extended towards the camshaft for forming form a reed valve chamber integrally provided with the head cover at a location at which the reed valve is disposed, the reed valve chamber being configured to accommodate the reed valve therein, and to a vehicle incorporating the same.

2. Description of the Background Art

There is a known internal combustion engine similar to as described above, for example, as shown in the Japanese Patent Publication No. Sho 62-53688.

It is sometimes required to increase the amount of secondary air introduced into an exhaust system depending on the cylinder capacity of an internal combustion engine. In such circumstances, it is necessary to increase the volume of a reed valve chamber. If it is tried to increase the swelling amount of an enlarged member (by extending the enlarged member) provided on a head cover to the camshaft side in order to satisfy such demand of increasing volume of the reed valve chamber, it is necessary to avoid interference of the enlarged member with a cam of the camshaft. It may also be necessary to avoid interference of the enlarged member with a cam cap which rotatably supports the camshaft with respect to the cylinder head.

Therefore, the swelling amount to the camshaft side is restricted, and where the volume is insufficient, it is necessary to form the enlarged member so as to be extended to the outside of the head cover to increase volume of the reed valve chamber.

However, if the enlarged member is extended (extended) to the outside of the head cover to assure a necessary volume for the reed valve chamber, increase in size of the head cover is required, and interference with some parts around the head cover becomes a problem.

The present invention has been made in view of the situation described above. Accordingly, it is one of the objects of the present invention to provide an internal combustion engine in which the volume of a reed valve chamber is increased while avoiding increase in size of a head cover of the engine.

SUMMARY OF THE INVENTION

In order to achieve the above objects, the present invention according to a first aspect thereof provides an internal combustion engine wherein a reed valve for controlling supply of

secondary air supplied to an exhaust system is disposed on a head cover. The head cover cooperates with a cylinder head for forming a valve motion chamber for accommodating a valve motion apparatus including a camshaft and a main enlarged member which is extended towards the camshaft for forming a reed valve chamber for accommodating the reed valve. The enlarged main member is integrally provided on the head cover at a location at which the reed valve is disposed. The present invention according to the first aspect thereof is characterized in that a recessed portion in which part of the main enlarged member is inserted is provided on a cam cap fastened to the cylinder head in such a manner as to cooperate with the cylinder head for rotatably supporting the camshaft.

Further, present invention according to a second aspect thereof, in addition to the first aspect, is characterized in that the cam cap includes a pair of bearing portions for sandwiching a plurality of cams provided on the camshaft therebetween and for cooperating with the cylinder head for rotatably supporting the camshaft. The cam cap also includes a connecting portion integrated with the bearing portions for connecting both of the bearing portions to each other. The recessed portion is provided on the connecting portion.

The present invention according to a third aspect thereof, in addition to one of the first and second aspects, is characterized in that that an extending portion is provided on the connecting portion such that a portion of the main enlarged member is disposed therein.

The present invention according to a fourth aspect thereof, in addition to one of the second and third aspects, is characterized in that a second enlarged member which is disposed between the pair of cams provided on the camshaft, and is further extended from the main enlarged member to the camshaft side is provided integrally on the main enlarged member.

The present invention according to a fifth aspect thereof, in addition to the fourth aspect, is characterized in that the second enlarged member is formed so as to be extended towards the camshaft until the second enlarged member coincides with a locus of rotation of a greater diameter from between loci of rotation of outer peripheries of the pair of cams as viewed from an axial direction of the camshaft.

The present invention according to a sixth aspect thereof, in addition to the third aspect, is characterized in that a reinforcing bridge disposed between the camshaft and the enlarged member is provided integrally on the connecting portion in such a manner that the extending portion is disposed on the opposite sides of the reinforcing bridge.

The present invention according to a seventh aspect thereof, in addition to one of the first through sixth aspects, is characterized in that a plurality of reed valve chambers individually corresponding to a plurality of reed valves disposed in an adjacent relationship to each other on the head cover are formed in a mutually adjacent relationship in the main enlarged member.

It may be noted that the exhaust side valve motion chamber **26**E in the embodiment corresponds to the valve motion chamber in the present invention, the exhaust side valve motion apparatus **39**E in the embodiment corresponds to the valve motion apparatus in the present invention, the exhaust side cam cap **41**E in the embodiment corresponds to the cam cap in the present invention, the exhaust side camshaft **42**E in the embodiment corresponds to the camshaft in the present invention, and the exhaust side cam **170** in the embodiment corresponds to the cam in the present invention.

Effects of the Invention

According to the first aspect of the present invention, since the recessed portion in which a portion of the main enlarged

member provided on the head cover for forming the reed valve chamber is provided on the cam cap fastened to the cylinder head, the extended amount of the main enlarged member towards the camshaft side can be increased while avoiding interference of the camshaft with the cam, and also avoiding interference of the camshaft with the cam cap. Also, a desired volume of the reed valve chamber can be assured without extending (swelling) the main enlarged member outwardly of the head cover.

According to the second characteristic of the present invention, since the cam cap has the pair of bearing portions for rotatably supporting the camshaft together with the cylinder head and the connecting portion integrated with the bearing portions for connecting both of the bearing portions to each other, and the recessed portion is provided on the connecting portion, it can be avoided that the supporting strength of the camshaft by the cam cap is dropped by provision of the recessed portion.

According to the third aspect of the present invention, since a portion of the main enlarged member is disposed on the extending portion provided on the connecting portion, it is possible to position the main enlarged members nearer to the camshaft side while avoiding interference with the cam cap, and reduction in weight by the main enlarged member can be anticipated within a range within which the strength of the cam cap does not drop.

According to the fourth aspect of the present invention, since the second enlarged member which is disposed between the pair of cams provided on the camshaft is further extended from the main enlarged member towards the camshaft, the volume of the reed valve chamber can be further increased while avoiding interference with the cam.

According to the fifth aspect of the present invention, since the second enlarged member is extended towards the camshaft until the second enlarged member coincides with the locus of rotation of a greater diameter from between the loci of rotation of the outer peripheries of the cams as viewed from the axial direction of the camshaft, the second enlarged member can be positioned more closely towards the camshaft for assuring desired volume of the reed valve chamber.

According to the sixth aspect of the present invention, since the reinforcing bridge disposed between the camshaft and the main enlarged member is provided integrally on the connecting portion in such a manner that the extending portion is disposed on the opposite sides of the reinforcing bridge, the connecting portion of the cam cap can be reinforced not to influence on the main enlarged member.

Further, according to the seventh aspect of the present invention, since the plural reed valve chambers disposed in an adjacent relationship to each other are formed in the main enlarged member, compact arrangement of the reed valves and the reed valve chambers can be anticipated.

For a more complete understanding of the present invention, the reader is referred to the following detailed description section, which should be read in conjunction with the accompanying drawings. Throughout the following detailed description and in the drawings, like numbers refer to like parts.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a right side elevational view of a motorcycle according an illustrative embodiment of the present invention.

FIG. **2** is a vertical sectional view of a four-cycle air-oil cooled internal combustion engine taken along line **2-2** of FIG. **3**.

FIG. **3** is a view taken along line **3-3** of FIG. **2**.

FIG. **4** is a view taken along line **4-4** of FIG. **3**.

FIG. **5** is a view taken along line **5-5** of FIG. **3**.

FIG. **6** is a plan view as viewed in the direction indicated by an arrow **6** in FIG. **3**.

FIG. **7** is an enlarged view as viewed in the direction indicated by an arrow **7** in FIG. **2**.

FIG. **8** is a perspective view of a cam cap.

FIG. **9** is a view of a crankcase, with an oil strainer removed, as viewed in the direction indicated by arrows **9-9** of FIG. **3**.

FIG. **10** is a sectional view taken along line **10-10** of FIG. **9**, and showing part of an oil path structure in a crankcase and an oil pan.

FIG. **11** is an enlarged sectional view taken along line **11-11** of FIG. **2**.

FIG. **12** is a sectional view taken along line **12-12** of FIG. **6**, and showing an oil jacket and a path leading to the oil jacket.

FIG. **13** is a sectional view taken along line **13-13** of FIG. **12**.

FIG. **14** is a front elevational view of an engine body mounted on a vehicle body frame as viewed in the direction indicated by an arrow **14** of FIG. **3**.

FIG. **15** is a view as viewed in the direction indicated by an arrow **15** of FIG. **3**.

FIG. **16** is a sectional view of a cylinder head taken along line **16-16** of FIG. **6**.

FIG. **17** is a sectional view taken along line **17-17** of FIG. **5**.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

An embodiment of the present invention will now be described, with reference to the drawings. Throughout this description, relative terms like "upper", "lower", "above", "below", "front", "back", and the like are used in reference to a vantage point of an operator of the vehicle, seated on the driver's seat and facing forward. It should be understood that these terms are used for purposes of illustration, and are not intended to limit the invention. Further, it should be noted that where a reference number is followed herein by multiple dots such as . . . , that is a short way of indicating that more than one of that referenced component is present in the assembled structure.

In the following, an embodiment of the present invention is described based on working examples of the present invention shown in the accompanying drawings.

Illustrative Embodiment 1

An illustrative embodiment (working example) 1 of the present invention is described with reference to FIGS. **1** to **17**.

As shown in FIG. **1**, a motorcycle according to the present invention includes a vehicle body frame F. The vehicle body frame F includes a head pipe **141** for supporting a front fork **140**, a main frame **142** extending rearwardly from the head pipe **141**, a pair of left and right center tubes **143** . . . extending downwardly from a rear end of the main frame **142**, a pair of left and right down tubes **144** . . . inclined rearwardly downward at a steeper angle than the main frame **142** from the head pipe **141**, a pair of left and right pivot plates **145** . . . individually provided at lower end portions of the center tubes **143**, . . . , and a pair of left and right seat rails **146** . . . extending

rearwardly from the pivot plates **145**, ... The front fork **140** has a front wheel WF supported at a lower end thereof for steering operation.

A steering handle member **147** is connected to an upper end of the front fork **140**. A rider's seat **148** is arranged on the seat rails **146**, ... A fuel tank **149** extending across the main frame **142** forwardly of the rider's seat **148** is supported by the main frame **142**.

An engine body **15** of a four-cycle in-line multi-cylinder air-oil cooled internal combustion engine is supported by the down tubes **144** . . . and the pivot plates **145**, . . . at a location surrounded by the main frame **142**, center tubes **143** . . . and down tubes **144** . . . .

Further, swing arms **150** . . . having rear end portions at which a rear wheel WR which is driven by the internal combustion engine, is supported for rotation at front end portions thereof on the pivot plates **145** for rocking motion on the pivot plates **145** . . . through a support shaft **151**. Rear shock absorbers **152** . . . are provided between the seat rails **146** . . . and the swing arms **150**, ...

Referring to FIGS. **2** and **3**, the engine body **15** includes a crankcase **16**, a cylinder block **17**, a cylinder head **18** and a head cover **19**. A plurality of cylinder block side cooling fins **17***a*, **17***a* . . . spaced from each other in a direction along a cylinder axial line CL are formed integrally in a projecting manner on a side face of the cylinder block **17**. A plurality of cylinder head side cooling fins **18***a*, **18***a* . . . spaced from each other in a direction along the cylinder axial line CL are provided integrally in a projecting manner on a side face of the cylinder head **18**.

An oil pan **20** is coupled to and arranged at the bottom of the engine body **15**, that is, attached to the bottom of the crankcase **16**. Further, the crankcase **16** is formed from an upper case half **16***a* and a lower case half **16***b* coupled to each other. A crankshaft **21** is supported for rotation between the upper and lower case halves **16***a* and **16***b*.

Referring also to FIGS. **4** and **5**, the engine body **15** includes first to fourth cylinders C**1** to C**4** juxtaposed in parallel to the axial line of the crankshaft **21**. Pistons **23** . . . fitted for sliding movement in cylinder bores **22**, **22** . . . provided in the cylinder block **17** for the individual cylinders C**1** to C**4** are connected commonly to the crankshaft **21**, and combustion chambers **24** . . . in which top portions of the pistons **23** . . . are opposed are formed between the cylinder block **17** and the cylinder head **18** for the individual cylinders C**1** to C**4**. The cylinder block **17** is coupled to the crankcase **16** such that the axial line of each of the cylinder bores **22**, **22**, . . . , that is, the cylinder axial line CL, is inclined forwardly.

Intake ports **28** . . . formed in a bifurcated form are provided for the individual cylinders C**1** to C**4** in the cylinder head **18** such that they are opened to a rear face **30** of the cylinder head **18**. Exhaust ports **29** formed in a bifurcated form are provided for the individual cylinders C**1** to C**4** in the cylinder head **18** such that they are opened to a front face **31** of the cylinder head **18**.

The opening ends of the intake ports **28** . . . to the combustion chambers **24** . . . are operated (opened and closed) by intake valves **32** . . . which are disposed for opening and closing movement in the cylinder head **18** and biased in a valve closing direction by springs. Opening ends of the exhaust ports **29** to the combustion chambers **24** . . . are operated (opened and closed) with exhaust valves **33** . . . which are disposed for opening and closing movement in the cylinder head **18** and biased in a valve closing direction by springs.

Throttle bodies **35** . . . having throttle valves **34** . . . are connected to the individual intake ports **28** . . . through insulators **36**, . . . , and fuel injection valves **37** . . . for injecting fuel toward the intake ports **28** . . . are provided for the throttle bodies **35**, ... Further, exhaust pipes **38** . . . are individually connected to the exhaust ports **29** (see FIG. **1**). The exhaust pipes **38** . . . are curved downwardly from the front face **31** of the cylinder head **18**, so as to pass below the engine body **15** and extend rearwardly.

Referring also to FIG. **6**, the head cover **19** includes a rear box-like portion **19***a* coupled to an upper portion of the cylinder head **18** to form an intake side valve motion chamber **26**I together with the cylinder head **18**, a front box-like portion **19***b* coupled to an upper portion of the cylinder head **18** to form an exhaust side valve motion chamber **26**E together with the cylinder head **18**, and a connecting portion **19***c* for connecting the rear box-like portion **19***a* and the front box-like portion **19***b* integrally to each other. The head cover **19** is formed in a substantially H shaped profile.

An intake side valve motion apparatus **391** for operating (driving open and close) the intake valves **32** . . . includes lifters **40**I . . . of a bottom cylindrical shape accommodated in the intake side valve motion chamber **261** formed between the cylinder head **18** and the head cover **19** for being contacted by stem ends at upper ends of the intake valves **32** . . . and being fitted for sliding movement in the cylinder head **18**, and an intake side camshaft **42**I extending in parallel to the crankshaft **21** commonly to the cylinders and supported for rotation between the cylinder head **18** and a plurality of cam caps **41**I . . . fastened to the cylinder head **18**. The lifters **40**I . . . are slidably moved upwardly and downwardly in response to rotation of the intake side camshaft **42**I to open and close the intake valves **32**, ...

An exhaust side valve motion apparatus **39**E for operating (driving open and close) the exhaust valves **33** . . . includes lifters **40**E . . . of a bottomed cylindrical shape accommodated in the exhaust side valve motion chamber **26**E formed between the cylinder head **18** and the head cover **19** for being contacted by stem ends at upper ends of the exhaust valves **33** . . . and being fitted for sliding movement in the cylinder head **18**, and an exhaust side camshaft **42**E extending in parallel to the crankshaft **21** commonly to the cylinders and supported for rotation between the cylinder head **18** and a plurality of exhaust side cam caps **41**E . . . fastened to the cylinder head **18**. The lifters **40**E . . . are slidably moved upwardly and downwardly in response to rotation of the exhaust side camshaft **42**E to open and close the exhaust valves **33**, ...

A timing driving mechanism **44** is provided between the intake side camshaft **42**I and exhaust side camshaft **42**E and the crankshaft **21** (see FIG. **2**). The timing driving mechanism **44** transmits rotational power of the crankshaft **21** to the intake side camshaft **42**I and the exhaust side camshaft **42**E at a speed reducing ratio of 1/2. A cam chain path **46** is provided over the crankcase **16**, cylinder block **17** and cylinder head **18** at a central location along the direction in which the cylinders are juxtaposed. The cam chain path **46** allows a cam chain **45**, which forms part of the timing driving mechanism **44**, to travel therealong.

Incidentally, an upper portion of the cylinder head **18** is formed such that a pair of plug attachment recessed portions **47** . . . are, in a state wherein the engine body **15** is carried on the motorcycle, open leftwardly and upwardly and open rightwardly and upwardly, respectively. The cam chain path **46** is positioned between the pair of plug attachment recessed portions **47**, ...

While ignition plugs **48** . . . having end portions opposed to central portions of the combustion chambers **24** . . . are attached to the cylinder head **18**, plug attachment holes **49** . . . for attaching the ignition plugs **48** . . . are provided on bottom portions of the plug attachment recessed portions **47** . . . at central locations of the combustion chambers **24**, ...

Referring also to FIG. **7**, reed valves **160**, **160** . . . for controlling supply of secondary air to the exhaust system of the internal combustion engine are disposed for the individual cylinders C**1** to C**4** in the front side box-like portion **19***b* of the head cover **19**. At the front box-like portion **19***b* of the head cover **19** at a location at which the reed valves **160** . . . are disposed, enlarged members **162** . . . which are extended to the exhaust side camshaft side in such a manner as to form reed valve chambers **161** . . . for accommodating the reed valves **160** . . . are provided integrally. A recessed portion **163** in which part of the enlarged members **162** . . . are fitted is provided on an exhaust side cam cap **41**E. The exhaust cap **41**E is fastened to the cylinder head **18** in such a manner as to cooperate with the cylinder head **18** for rotatably supporting the exhaust side camshaft **42**E.

The reed valves **160** are disposed for the individual cylinders C**1** to C**4**. In the present working example 1, reed valves **160**, **160** for two cylinders are disposed adjacent to each other. Two enlarged members **162** . . . which form a pair of reed valve chambers **161**, **161** . . . for individually accommodating two sets of pairs of reed valves **160**, **160** . . . are positioned adjacent to each other. A pair of housings **164** . . . integrally having connecting pipes **164***a* . . . to which conduits for introducing secondary air from an air cleaner (not shown) are connected to an outer face of the front box-like portion **19***b*, in such a manner as to cover a portion of the front box-like portion **19***b* of the head cover **19** at which the enlarged members **162** . . . are formed.

Each reed valve **160** is attached to a ring shaped support member **165**. The support members **165** for one pair of reed valves **160** . . . are sandwiched between the front box-like portion **19***b* of the head cover **19** and a housing **164**. Further, a barrier **164***b* for partitioning the housing **164** into a pair of air introduction chambers **166** and **167** individually corresponding to a pair of reed valves **160** . . . is provided integrally on the housing **164**. A communicating hole **168** for communicating the air introduction chambers **166** and **167** with each other is formed in the barrier **164***b*. Further, a barrier **162***b* for forming a pair of reed valve chambers **161** . . . individually corresponding to a pair of reed valves **160** . . . positioned adjacent each other in an adjacent relationship to each other in a main enlarged member **162** is provided integrally on the main enlarged member **162**.

As shown in FIG. **3**, a plurality of secondary air paths **169** . . . communicating at one end thereof with the reed valve chambers **161** . . . are provided in the head cover **19** and the cylinder head **18** The secondary air paths **169** . . . are open at the other end thereof to the exhaust ports **29** . . . of the cylinders C**1** to C**4**.

Referring also to FIG. **8**, the exhaust side cam cap **41**E integrally has thereon a pair of bearing portions **171**, **171** which sandwich therebetween two exhaust side cams **170**, **170**. The exhaust side cams **170**, **170** are provided on the exhaust side camshaft **42**E individually corresponding to the two exhaust valves **33**, **33** positioned adjacent each other from among the exhaust valves **33** . . . of a plurality of exhaust side cams provided on the exhaust side camshaft **42**E. For example, of two ones of the first to fourth cylinders C**1** to C**4** and support the exhaust side camshaft **42**E for rotation together with the cylinder head **18**, and a connecting portion **172** for connecting the two bearing portions **171**, **171** to each other. The recessed portion **163** is provided on the connecting portion **172**.

Besides, a second main enlarged member **162***a* . . . is further extended from each main enlarged member **162** toward the exhaust side camshaft **42**E side is provided integrally on the main enlarged member **162**. The second main enlarged member **162***a* . . . is disposed between a pair of exhaust side cams **170**, **170** provided on the exhaust side camshaft **42**E and is further extended from each main enlarged member **162** toward the exhaust side camshaft **42**E side is provided integrally on the main enlarged member **162**. The second main enlarged member **162***a* is formed so as to be extended to the exhaust side camshaft **42**E side until it coincides with a locus of rotation of a greater diameter from between loci C of rotation of outer circumferences of a pair of exhaust side cams **170**, **170** as viewed from the axial direction of the exhaust side camshaft **42**E. In the present working example 1, with the locus TC of rotation of the outer circumference of both exhaust side cams **170**, **170** because the loci C of rotation of the outer circumferences of both exhaust side cams **170**, **170** have an equal diameter.

In addition, the extending portions **173**, **173** are provided on the connecting portion **172**, in a manner such that part of the enlarged members **162** . . . is disposed therein and a reinforcing bridge **174** which is disposed between the exhaust side camshaft **42**E and the main enlarged member **162** is provided integrally such that the extending portions **173**, **173** are disposed on the opposite sides of the reinforcing bridge **174**.

On the bearing portions **171** . . . of the exhaust side cam cap **41**E, cylindrical attachment bosses **171***a*, **171***a* which extend through the front box-like portion **19***b* of the head cover **19** are provided integrally on the bearing portions **171** . . . of the exhaust side cam cap **41**E, and bolts **175** . . . are screwed in the attachment bosses **171***a*, **171***a*. Annular resilient members **1786** . . . are sandwiched between increased diameter head portions **175***a* . . . of the bolts **175** . . . and the front box-like portion **19***b* of the head cover **19** to attach the head cover **19** to the cylinder head **18** side.

As shown in FIG. **2**, a generator **50** is connected to one end of the crankshaft **21**. The generator **50** is accommodated in a generator chamber **52** formed between a side cover **51** coupled to the crankcase **16** and the crankcase **16**. Rotary power of the crankshaft **21** is transmitted through an endless chain **53** to the rear wheel WR of the motorcycle. The rotary power of the crankshaft **21** is transmitted to the chain **53** through a primary reduction gear **54**, a damper spring **55**, a starting clutch **56** and a gear transmission **57**.

The gear transmission **57** includes a main shaft **58** to which rotary power of the crankshaft **21** is inputted through the primary reduction gear **54**, damper spring **55** and starting clutch **56**, a countershaft **59** having an axial line parallel to the main shaft **58** and having a projecting portion which projects from the crankcase **16** and to which a driving sprocket wheel **61** around which the chain **53** is wrapped is secured, gear wheel trains of a plurality of speed change stages. For example, first to fifth speed gears G**1**, G**2**, G**3**, G**4** and G**5** are provided between the main shaft **58** and the countershaft **59** for allowing selective establishment, and a shift drum **60** (refer to FIG. **3**) rotatable around an axial line parallel to the main shaft **58** and the countershaft **59** are provided for allowing selective establishment of the first to fifth speed gears G**1** to G**5** in response to rotational operation thereof. The gear transmission **57** is disposed in the crankcase **16**. Besides, the

main shaft **58** and the countershaft **59** are supported for rotation between the upper and lower case halves **16***a* and **16***b* which form the crankcase **16**.

Referring also to FIGS. **9** and **10**, a cooling oil pump **63** and a lubricating oil pump **64** have a common pump shaft **65** such that they are formed as a unit and are disposed on the bottom of the crankcase **16**. Further, an oil strainer **66** is accommodated in the oil pan **20** coupled to the bottom of the crankcase **16**, and an upper portion of an oil intake pipe **67** which extends upwardly from the oil strainer **66** is fitted in from below and secured to an intake path **68** which is provided commonly in the cooling oil pump **63** and the lubricating oil pump **64**. The cooling oil pump **63** and the lubricating oil pump **64** pump up oil from the oil pan **20** through the oil strainer **66**, and power is transmitted from the crankshaft **21** to the pump shaft **65**.

A lubricating discharge pipe **69** connecting to the lubricating oil pump **64** is curved in the oil pan **20** and extends forwardly (rightwardly in FIG. **9** and leftwardly in FIG. **10**), and is connected to an oil filter **71** attached to a front wall **70** from among side walls of the crankcase **16** which is opposed forwardly in a state wherein the engine body **15** is carried on the motorcycle. Further, a main gallery **72** is provided on the lower case half **16***b* of the crankcase **16**, and an oil filter exit path **73** which extends from a central portion of the oil filter **71** is communicated with the main gallery **72**.

Referring also to FIG. **11**, journal portions **21***a* . . . for being supported for rotation between the upper and lower case halves **16***a* and **16***b* of the crankcase **16** are provided on the crankshaft **21** between adjacent ones of the cylinders C**1** to C**4**. Annular lubrication chambers **74** . . . are formed between the journal portions **21***a* . . . and the upper and lower case halves **16***a* and **16***b* of the crankcase **16**, and oil paths **75** . . . which are branched from the main gallery **72** and directed to the plural lubrication chambers **74** . . . are provided in the lower case half **16***b*.

An oil jet path **76** is provided in the cylinder block **17** between the first and second cylinders C**1** and C**2** and between the third and fourth cylinders C**3** and C**4** . . . as shown in FIG. **2**. Oil from the lubrication chambers **74** . . . is introduced to the oil jet paths **76** . . . through oil paths **77** . . . provided in the upper case half **16***a*.

Besides, substantially T-shaped distribution pipes **78** . . . are connected to the oil jet paths **76**, . . . , and injection nozzles **79**, **79** for injecting oil toward the pistons **23** . . . of the first and second cylinders C**1** and C**2** are attached to the distribution pipe **78** connected to the oil jet path **76** between the first and second cylinders C**1** and C**2** while injection nozzles **79**, **79** for injecting oil toward the pistons **23** . . . of the third and fourth cylinders C**3** and C**4** are attached to the distribution pipe **78** connected to the oil jet path **76** between the third and fourth cylinders C**3** and C**4**.

Further, oil from the main gallery **72** is supplied for lubrication to the intake side valve motion apparatus **391** and the exhaust side valve motion apparatus **39**E through oil paths (not shown) provided in the cylinder block **17** and the cylinder head **18**.

Referring to FIGS. **12** and **13**, oil jackets **81** . . . for communicating oil pressure fed from the cooling oil pump **63** are formed for the individual cylinders C**1** to C**4** in such a manner as to surround the plug attachment holes **49**, ... Each oil jacket **81** is formed such that an opening end of a ring-shaped groove **82** provided on the cylinder head **18** in such a manner as to surround a plug attachment hole **49** is formed in a ring surrounding an ignition plug **48** and is closed up with a lid member **83** serving as a fixed member fastened to the cylinder head **18**. A plurality of cooling fins **83***a*, **83***a* is formed integrally on the lid member **83**.

Flat seal faces **84** disposed in a plane perpendicular to the axial line of the plug attachment hole **49** and connecting in an endless fashion to each other in so as to sandwich the opening end of the groove **82** from the inner side and the outer side on the cylinder head **18**. The lid member **83** having a flat face **86** opposing to the seal face **84** is fastened to the cylinder head **18** by a pair of bolts **88**, **88** spaced from each other in the cylinder arrangement direction as seen in FIGS. **6** and **13** such that a seal member **87** is interposed between the seal faces **84** . . . and the flat faces **86**. The ignition plug **48** is inserted in a plug insertion hole **89** provided at a central portion of the lid member **83** and is screwed in a plug attachment hole **49** of the cylinder head **18**.

Further, on the cylinder head **18**, introduction side oil paths **91** . . . for introducing oil from the exhaust ports **29** . . . side to the oil jackets **81** . . . of the cylinders C**1** to C**4** and derivation side oil paths **92** . . . for deriving oil from the oil jackets **81** . . . of the cylinders C**1** to C**4** to the intake ports **28** side are provided. The introduction side oil paths **91** . . . and the derivation side oil paths **92** . . . are disposed on a plane which extends perpendicularly to the cylinder arrangement direction and passes the cylinder axial line CL.

Referring also to FIG. **14**, the introduction side oil paths **91** . . . of the first and second cylinders C**1** and C**2** are communicated with a introduction side first common path **93** formed between the cylinder block **17** and the cylinder head **18** at locations corresponding to the first and second cylinders C**1** and C**2**. The introduction side oil paths **91** . . . of the third and fourth cylinders C**3** and C**4** . . . are communicated with the introduction side first common path **93** formed between the cylinder block **17** and the cylinder head **18** at locations corresponding to the third and fourth cylinders C**3** and C**4**, ...

Further, a pair of paths **94**, **94** extending upwardly and downwardly and individually communicating at one end thereof to a pair of introduction side first common paths **93** are provided on the cylinder block **17**. The paths **94**, **94** are communicated at the other end thereof to the opposite ends of a introduction side second common path **95** provided in the front wall of the cylinder block **17** and extending in the cylinder arrangement direction.

Referring also to FIG. **15**, the derivation side oil paths **92** . . . of the first and second cylinders C**1** and C**2** are communicated with a derivation side first common path **96** formed between the cylinder block **17** and the cylinder head **18** at a location corresponding to the first and second cylinders C**1** and C**2**. The derivation side oil paths **92** . . . of the third and fourth cylinders C**3** and C**4** . . . are communicated with the derivation side first common path **96** formed between the cylinder block **17** and the cylinder head **18** at a location corresponding to the third and fourth cylinders C**3** and C**4**, ...

Further, a pair of paths **97**, **97** individually communicated at one end thereof with a pair of derivation side first common paths **96**, **96** and extending upwardly and downwardly are provided on the cylinder block **17**. The paths **97**, **97** are communicated at the other end thereof to the opposite ends of a derivation side second common path **98** provided in the front wall of the cylinder block **17** in such a manner as to extend in the cylinder arrangement direction over the first to fourth cylinders C**1** to C**4**. Further, a path **99** extending upwardly and downwardly and communicated at one end thereof with a substantially central portion of the derivation side second common path **98** is provided in the upper case half **16***a* of the crankcase **16**.

A pipe member **100** extending upwardly and downwardly and placing a lower end opening thereof in the oil pan **20** is fitted liquid tight with a lower end portion of the path **99** at an upper end portion thereof, and a support plate **101** secured to a lower portion of the pipe member **100** is fastened to the lower case half **16***b* of the crankcase **16** by a bolt **102**. An oil temperature sensor **103** is provided on the front wall of the cylinder block **17** in such a manner as to detect the temperature of oil circulating along the derivation side second common path **98**.

Referring again to FIG. **10**, to a branching portion **139** provided on a cooling oil discharge pipe **138** communicating with a discharge port of the cooling oil pump **63** and accommodated in the oil pan **20**, an oil cooling circuit **105** having an oil cooler **104** (refer to FIG. **14**) and a bypass circuit **106** which bypasses the oil cooling circuit **105** are connected.

A thermostat **107** for controlling the circulation of oil discharged from the cooling oil pump **63** to the oil cooling circuit **105** and the bypass circuit **106** is disposed at the branching portion **139**. Besides, the branching portion **139** is formed from a thermostat accommodating case **108** connected to the cooling oil discharge pipe **138** in such a manner as to accommodate and secure the thermostat **107**.

The thermostat accommodating case **108** includes an upper case **109** of a bottomed cylindrical shape open at a lower portion thereof and a lower case **110** formed in a bottomed cylindrical shape open at an upper portion thereof and fitted from below with the upper case **109**. The thermostat accommodating case **108** is attached at a lower portion thereof to the oil pan **20**.

A connecting pipe **112** of a bottomed cylindrical shape extending in a mounting and dismounting direction of the oil pan **20** on and from the crankcase **16**, that is, in the upward and downward direction and connecting to the cooling oil discharge pipe **138** is fitted at a lower portion thereof liquid tight with an upper portion of the thermostat accommodating case **108**. An upper end closed portion of the connecting pipe **112** is abutted by a plug member **114** secured to the crankcase **16** in such a manner as to close up a lower end portion of a communicating hole **113** provided in the crankcase **16** in such a manner as to communicate the oil filter exit path **73** extending from a central portion of the oil filter **71** with the main gallery **72**.

A relief valve **115** is connected to the discharge port of the lubricating oil pump **64**. The relief valve **115** is fitted at an upper portion thereof with the crankcase **16** liquid tight from below in such a manner as to be connected to an entrance side path **116** provided in the crankcase **16** such that the lubricating discharge pipe **69** connecting to the lubricating oil pump **64** is connected to the oil filter **71**.

An arcuate supporting projection **109***a* for abutting with and supporting a lower end of the relief valve **115** is provided in a projecting manner on the upper case **109** of the thermostat accommodating case **108** attached to the oil pan **20** coupled to the bottom of the crank case **116**.

The oil cooling circuit **105** includes a first oil conduit **119** connected at one end portion thereof to the thermostat accommodating case **108** and connected and supported at the other end thereof to and by an inner face of the front wall of the crankcase **16**, a second oil conductor **120** connected at an end portion thereof to the inner face of the front wall of the crankcase **16** in such a manner as to connect to the other end of the first oil conduit **119** and connected at the other end portion thereof to the oil cooler **104** as shown in FIG. **14**, and a third oil conduit **121** for deriving oil cooled by the oil cooler **104** from the oil cooler **104**. The oil cooler **104** is supported on the down tubes **27** . . . of the vehicle body frame F in such a manner as to be positioned upwardly with respect to the cylinder block **17** of the engine body **15** and forwardly with respect to the engine body **15**.

The bypass circuit **106** includes a fourth oil conduit **124** connected at an end portion thereof to the thermostat accommodating case **108** and connected and supported at the other end portion thereof to and by the inner face of the front tall of the crankcase **16**, and a fifth oil conduit **125** connected at one end thereof to the outer face of the front wall of the crankcase **16** at a position at which the oil filter **71** is sandwiched by a connecting point of the second oil conductor **120** to the crankcase **16** and the fifth oil conduit **125** and communicating with the fourth oil conduit **124**. The fifth oil conduit **125** is communicated at the other end thereof with a central portion of the introduction side second common path **95**.

Further, the third oil conduit **121** which forms part of the oil cooling circuit **105** and extends downwardly from the oil cooler **104** is communicated, at a lower end portion thereof with the introduction side second common path **95**. In particular, the oil cooling circuit **105** having the oil cooler **104** for cooling part of oil discharged from the cooling oil pump **63** for introducing the oil cooled by the oil cooler **104** to the introduction side second common path **95** is provided between the cooling oil pump **63** and the introduction side second common path **95**.

A pair of drain holes **135**, **135** for discharging water entering the plug insertion hole **89** to the upper face side of the cylinder head **18**, that is, to the recessed portion **47** side, are provided in the lid member **83** as shown in FIG. **12**. The drain holes **135** . . . and the cooling fins **83***a* . . . are formed such that they are symmetrical with respect to a plane which extends perpendicularly to the cylinder arrangement direction and passes the cylinder axial line CL so that, even if the forward and backward directions of the lid member **83** with respect to the cylinder head **18** are reversed from each other, the relative posture thereof with respect to the cylinder head **18** is same.

The drain holes **135** . . . are formed such that the drain hole **135** disposed on the front side in a state wherein the lid member **83** is attached to the cylinder head **18** of the engine body **15** whose cylinder axial line CL is inclined forwardly extends horizontally or forwardly downwards.

Referring to FIG. **16**, traveling wind communicating holes **126**, **126** opened at one end thereof to the front face of the cylinder head **18** and opened at the other end thereof to the plug attachment recessed portions **47** . . . and traveling wind communicating holes **127**, **127** opened at one end thereof to the plug attachment recessed portions **47** . . . and opened at the other end thereof to the rear face of the cylinder head **18** are provided between the first and second cylinders C**1** and C**2** and between the third and fourth cylinders C**3** and C**4** . . . of the cylinder head **18** such that, when the motorcycle travels, traveling wind may be circuited therein.

Accordingly, water gathered at portions of the plug attachment recessed portions **47**, **47** corresponding to the second and third cylinders C**2** and C**3** and water discharged from the drain holes **135** . . . of the second and third cylinders C**2** and C**3** to the plug attachment recessed portions **47**, **47** are discharged from the traveling wind communicating holes **126** . . . which extend forwardly downwards from between the traveling wind communicating holes **126** . . . and **127** . . . to the front face side of the cylinder head **18** as indicated arrow marks in FIG. **6**.

Meanwhile, water gathered in the plug attachment recessed portions **47**, **47** at portions on the cylinders at the opposite ends in the cylinder arrangement direction, that is, on the first and fourth cylinders C**1** and C**4** and water discharged from the drain holes **135** . . . of the lid members **83** . . . of the first and

fourth cylinders C1 and C4 to the plug attachment recessed portions **47**, **47** are difficult to communicate with the traveling wind communicating hole **126** side.

Therefore, first drain paths **128**, **128** for introducing water from the plug attachment recessed portions **47** . . . to the cylinder block **17** side are formed in the cylinder head **18** at the opposite end portions in the cylinder arrangement direction in such a manner as to be open to the upper face of the cylinder head **18**, and second drain paths **129** . . . connecting to the first drain paths **128** . . . are provided on the cylinder block **17** side in such a manner as to be open to the front face or the rear face of the cylinder block **17**, in the present working example 1, to the front face.

In addition, the first drain path **128** is provided on the cylinder block **17** in such a manner as to extend in a direction along the cylinder axial line CL, and is disposed on the inner side of a plurality of cylinder head side cooling fins **18***a*, **18***a* . . . provided in a projecting manner on a side face of the cylinder head **18** and is disposed in such a manner as to be positioned adjacent from the inner side to vertical ribs **18***b* which interconnect the plural cylinder head side cooling fins **18***a*, **18***a*, ...

Further, the first drain path **128** is formed such that it has an arcuate transverse sectional shape extending along the outer circumference of a cylinder bore **22** as viewed from a direction along the cylinder axial line CL.

Referring to FIG. **17**, a path portion **130** which forms part of a second drain path **129** is formed from a groove **131** provided on a deck face **17***b* of the cylinder block **17** and communicated at one end thereof with the first drain path **128**, and the cylinder head **18** coupled to the deck face **17***b*. The second drain path **129** is formed from the path portion **130** described hereinabove, a vertical hole **132** provided in the cylinder head **18** so as to extend in a direction parallel to the cylinder axial line CL and having an end communicated with the other end of the groove **131**, and a transverse hole **133** provided in the cylinder block **17** in such a manner as to be communicated at an end thereof with the other end of the vertical hole **132** and opened at the other end thereof to the front face of the cylinder block **17**.

The transverse hole **133** is situated between a pair of cylinder block side cooling fins **17***a*, **17***a* . . . which are positioned adjacent each other from among the plural cylinder block side cooling fins **17***a*, **17***a* . . . provided in a projecting manner on the side face of the cylinder block **17**.

Now, operation of the present working example 1 is described.

The reed valves **160** . . . for controlling supply of secondary air to the exhaust system are disposed on the head cover **19**. The enlarged members **162** . . . extended to the exhaust side camshaft **42**E so as to form the reed valve chambers **161** . . . for accommodating the reed valves **160** . . . therein are provided integrally at a portion of the head cover **19** at which the reed valves **160** . . . are disposed. The recessed portion **163** into which part of the main enlarged member **162** fitted is provided on the exhaust side cam cap **41**E fastened to the cylinder head **18** such that it cooperates with the cylinder head **18** to support the exhaust side camshaft **42**E for rotation.

Therefore, the extended amount of the enlarged members **162** to the exhaust side camshaft **42**E side can be increased while avoiding interference of the exhaust side camshaft **42**E with the exhaust side cams **170** . . . and interference of the exhaust side camshaft **42**E with the exhaust side cam cap **41**E, and the volume of the reed valve chambers **161** . . . can be assured without swelling the enlarged members **162** . . . to the outer side of the head cover **19**.

Further, since the exhaust side cam cap **41**E has a pair of bearing portions **171**, **171** which sandwich a plurality of, for example, a pair of exhaust side cams **170** . . . provided on the exhaust side camshaft **42**E and cooperate with the cylinder head **18** to support the exhaust side camshaft **42**E for rotation, and a connecting portion **172** integrated with the bearing portions **171** . . . for connecting both bearing portions **171** . . . to each other and the recessed portion **163** is provided on the connecting portion **172**, it can be avoided that the supporting strength of the exhaust side camshaft **42**E by the exhaust side cam cap **41**E is dropped by provision of the recessed portion **163**.

In addition, since the extending portions **173** . . . are provided on the connecting portion **172** such that part of the enlarged members **162** is disposed thereon, it is possible to position the enlarged members **162** nearer to the exhaust side camshaft **42**E while avoiding interference with the exhaust side cam cap **41**E, and reduction in weight by the enlarged members **162** can be anticipated within a range within which the strength of the exhaust side cam cap **41**E does not drop.

Since the second main enlarged member **162***a* disposed between the pair of exhaust side cams **170** . . . disposed on the exhaust side camshaft **42**E are provided integrally on the enlarged members **162** such that it is extended further from the enlarged members **162** to the exhaust side camshaft **42**E side, the volume of the reed valve chambers **161** . . . can be further increased while avoiding interference with the exhaust side cams **170**, ...

Since the second main enlarged member **162***a* is formed such that it is extended to the exhaust side camshaft **42**E side until it coincides with the locus TC of rotation having a greater diameter from between the loci of rotation of the outer circumferences of the pair of exhaust side cams **170** . . . as viewed from the axial direction of the exhaust side camshaft **42**E, the second main enlarged member **162***a* can be positioned more closely to the exhaust side camshaft **42**E side to assure the volume of the reed valve chambers **161**, ...

Further, since the reinforcing bridge **174** is provided integrally on the connecting portion **172** of the exhaust side cam cap **41**E in such a manner as to be disposed between the exhaust side camshaft **42**E and the enlarged members **162** and the extending portions **173**, **173** are disposed on the opposite sides of the reinforcing bridge **174**, the connecting portion **172** of the exhaust side cam cap **41**E can be reinforced not to influence on the main enlarged member **162**.

Further, since a pair of reed valve chambers **161** . . . individually corresponding to a plurality of, for example, a pair of, reed valves **160** . . . disposed on the head cover **19** positioned adjacent each other are formed in a mutually adjacent relationship in the enlarged members **162**, compact arrangement of the reed valves **160** . . . and the reed valve chambers **161** . . . can be realized.

Further, to the cylinder head **18**, the lid members **83** . . . having the plug insertion holes **89** . . . and the drain holes **135** . . . for draining water from the plug insertion holes **89** . . . are fastened for the individual cylinders C1 to C4, and the first drain paths **128** . . . for introducing water discharged from the plug insertion holes **89** . . . of the lid members **83** . . . corresponding to the first and fourth cylinders C1 and C4 to the cylinder block **17** side are provided in the cylinder head **18** while the second drain paths **129** . . . connecting to the first drain paths **128** . . . are provided on the cylinder block **17** side in such a manner as to be open to the front face of the cylinder block **17**.

However, the path portion **130** which forms part of the second drain path **129** is formed from the groove **131** provided on the deck face **17***b* of the cylinder block **17** with one

end thereof communicated with the first drain path **128** and the cylinder head **18** coupled to the deck face **17***b*. Therefore, even where interference with another member becomes a problem if a portion of the second drain path **129** near to the cylinder block **17** is formed linearly, the groove **131** can be crooked freely. Accordingly, it is easy to avoid interference with another member and it is possible to raise the degree of freedom in setting of the water draining direction.

Further, since the second drain path **129** includes the path portion **130**, the vertical hole **132** provided in the cylinder block **17** so as to extend in a direction parallel to the cylinder axial line CL and communicated at an end thereof with the other end of the groove **131**, and the transverse hole **133** provided on the cylinder block **17** such that it is communicated at an end thereof with the other end of the vertical hole **132** and is open at the other end thereof to the front face of the cylinder block **17**.

Therefore, the structure that water is discharged to the outside from the front face of the cylinder block **17** at a position spaced from the deck face **17***b* of the cylinder block **17** and the opposite ends of the groove **131** are closed, and consequently, drop of the strength of the cylinder block **17** by provision of the groove **131** can be suppressed.

Further, since the transverse hole **133** is disposed between a pair of cylinder block side cooling fins **17***a*, **17***a* which are positioned adjacent each other from among a plurality of cylinder block side cooling fins **17***a* . . . provided in a projecting manner on a side face of the cylinder block **17** in a spaced relationship from each other in a direction along the cylinder axial line CL, the opening end of the transverse hole **133** can be made less conspicuous and the influence of the disposition of the transverse hole **133** on the shape of the cylinder block side cooling fins **17***a*, **17***a* . . . which have an influence on the appearance of the internal combustion engine can be suppressed.

Since the first drain paths **128** are provided on the inner side of the plural cylinder head side cooling fins **18***a*, **18***a* . . . provided in a projecting manner on the side face of the cylinder head **18** in a spaced relationship in a direction along the cylinder axial line CL and is provided on the cylinder head **18** such that it extends in the direction along the cylinder axial line CL, the influence of the provision of the first drain paths **128** on the shape of the cylinder head side cooling fins **18***a*, **18***a* . . . can be suppressed and deterioration of the appearance of the internal combustion engine can be prevented.

Further, since the vertical ribs **18***b* which interconnect the plural cylinder head side cooling fins **18***a*, **18***a* . . . are provided on the cylinder head **18** and the first drain paths **128** are disposed such that they are positioned adjacent the vertical ribs **18***b* from the inner side, a drop of the intensity of the cylinder head **18** by the provision of the first drain paths **128** can be suppressed.

Further, since water is discharged from the plug insertion holes **89** . . . of the lid members **83** . . . corresponding to the first and fourth cylinders C**1** and C**4** to the upper face of the cylinder head **18** through the drain holes **135** . . . and, while the water flows along a ceiling portion of the combustion chambers **24** formed between the cylinder head **18** and the cylinder block **17**, the first drain paths **128** . . . which are open at an end thereof to the upper face of the cylinder head **18** are formed so as to have an arcuate transverse cross section extending along the outer circumference of the cylinder bores **22** as viewed from a direction along the cylinder axial line CL, the water discharged to the upper face of the cylinder head **18** can be introduced to the first drain paths **128** side without residing there as far as possible.

While an embodiment of the present invention has been described, the present invention is not restricted to the embodiment described above but various changes of design can be carried out without departing from the present invention as described in the claims.

In other words, although the present invention has been described herein with respect to a number of specific illustrative embodiments, the foregoing description is intended to illustrate, rather than to limit the invention. Those skilled in the art will realize that many modifications of the illustrative embodiment could be made which would be operable. All such modifications, which are within the scope of the claims, are intended to be within the scope and spirit of the present invention.

What is claimed is:

1. An internal combustion engine, comprising

a cylinder head;

an exhaust system;

a head cover cooperating with said cylinder head for forming a valve motion chamber;

a reed valve for controlling supply of secondary air to the exhaust system; said reed valve being disposed on said head cover;

a cam cap fastened to said cylinder head; and

a valve motion control apparatus disposed in said valve motion chamber, said valve motion control apparatus comprising:

a camshaft; and

a main enlarged member extended towards said camshaft for forming a reed valve chamber for accommodating said reed valve therein; said main enlarged member being integrally provided on said head cover at a location at which said reed valve is disposed;

wherein said cam cap includes a recessed portion formed thereon;

and wherein said recessed portion in which a portion of the main enlarged member is inserted is provided on the cam cap fastened to said cylinder head so as to cooperate with said cylinder head for rotatably supporting said camshaft.

2. An internal combustion engine according to claim **1**, wherein said cam cap comprises

a pair of bearing portions for sandwiching a plurality of cams provided on said camshaft therebetween, and for cooperating with said cylinder head for rotatably supporting said camshaft; and

a connecting portion integrated with said bearing portions for operatively connecting both of said bearing portions to each other;

wherein said recessed portion is provided on said connecting portion.

3. An internal combustion engine according to claim **2**, wherein said cam cap further comprises an extending portion provided on said connecting portion such that a portion of said main enlarged member is disposed on the extending portion.

4. An internal combustion engine according to claim **2**, wherein said main enlarged member has a second enlarged member integrally provided thereon; and wherein said second enlarged member is disposed between said pair of cams provided on said camshaft, and wherein said second enlarged member is further extended from said main enlarged member towards said camshaft.

5. An internal combustion engine according to claim **4**, wherein said second enlarged member is extended towards said camshaft such that said second enlarged member coincides with a locus of rotation of a greater diameter formed

between loci of rotation of outer peripheries of said pair of cams when viewed from an axial direction of said camshaft.

6. An internal combustion engine according to claim **5**, further comprising a plurality of reed valve chambers individually corresponding to a plurality of reed valves disposed in an adjacent relationship to each other on said head cover; wherein said plurality of reed valve chambers are formed in a mutually adjacent relationship in said main enlarged member.

7. An internal combustion engine according to claim **4**, further comprising a plurality of reed valve chambers individually corresponding to a plurality of reed valves disposed in an adjacent relationship to each other on said head cover; wherein said plurality of reed valve chambers are formed in a mutually adjacent relationship in said main enlarged member.

8. An internal combustion engine according to claim **2**, further comprising a plurality of reed valve chambers individually corresponding to a plurality of reed valves disposed in an adjacent relationship to each other on said head cover; wherein said plurality of reed valve chambers are formed in a mutually adjacent relationship in said main enlarged member.

9. An internal combustion engine according to claim **1**, wherein said cam cap comprises a connecting portion and an extending portion provided on the connecting portion; and

wherein a portion of said main enlarged member is disposed on said extending portion.

10. An internal combustion engine according to claim **9**, wherein said main enlarged member has a second enlarged member integrally provided thereon; and wherein said second enlarged member is disposed between said pair of cams provided on said camshaft, and wherein said second enlarged member is further extended from said main enlarged member towards said camshaft.

11. An internal combustion engine according to claim **9**, further comprising a reinforcing bridge disposed between said camshaft and said main enlarged member; wherein said reinforcing bridge is provided integrally on said connecting portion such that said extending portion is disposed on the opposite sides of said reinforcing bridge.

12. An internal combustion engine according to claim **11**, further comprising a plurality of reed valve chambers individually corresponding to a plurality of reed valves disposed in an adjacent relationship to each other on said head cover; wherein said plurality of reed valve chambers are formed in a mutually adjacent relationship in said main enlarged member.

13. An internal combustion engine according to claim **9**, further comprising a plurality of reed valve chambers individually corresponding to a plurality of reed valves disposed in an adjacent relationship to each other on said head cover; wherein said plurality of reed valve chambers are formed in a mutually adjacent relationship in said main enlarged member.

14. An internal combustion engine according to claim **1**, further comprising a plurality of reed valve chambers individually corresponding to a plurality of reed valves disposed in an adjacent relationship to each other on said head cover; wherein said plurality of reed valve chambers are formed in a mutually adjacent relationship in said main enlarged member.

15. An internal combustion engine, comprising

a plurality of cylinders;

a cylinder head operatively connected to said plurality of cylinders;

an exhaust system;

a head cover cooperating with said cylinder head for forming a valve motion chamber;

a plurality of reed valves for controlling supply of secondary air to the exhaust system; said reed valves being disposed on said head cover;

a cam cap fastened to said cylinder head; and

a valve motion control apparatus disposed in said valve motion chamber;

said valve motion apparatus comprising

a camshaft; and

a main enlarged member extended towards said camshaft, and having a barrier for forming a plurality of reed valve chambers therein; each of said reed valve chambers accommodating respective one of said reed valves therein; said main enlarged member being integrally provided on said head cover at a location at which respective said reed valves are disposed;

wherein

said cam cap includes a recessed portion formed thereon; and

said recessed portion in which a portion of the main enlarged member is inserted is provided on the cam cap fastened to said cylinder head so as to cooperate with said cylinder head for rotatably supporting said camshaft.

16. An internal combustion engine according to claim **15**, wherein

said cam cap comprises

a pair of bearing portions for sandwiching a plurality of cams provided on said camshaft therebetween, said pair of bearing portions being cooperating with said cylinder head for rotatably supporting said camshaft; and

a connecting portion integrated with said bearing portions for operatively connecting both of said bearing portions to each other;

wherein said recessed portion is provided on said connecting portion.

17. An internal combustion engine according to claim **16**, wherein said cam further comprises an extending portion provided on said connecting portion such that a portion of said main enlarged member is disposed thereon;

wherein said main enlarged member has a second enlarged member integrally provided thereon; and wherein said second enlarged member is disposed between said pair of cams provided on said camshaft, and

wherein said second enlarged member is further extended from said main enlarged member towards said camshaft.

18. A motorcycle having a four cycle air-cooled internal combustion engine, said engine comprising

a plurality of cylinders;

a cylinder head operatively connected to said plurality of cylinders;

an exhaust system;

a head cover cooperating with said cylinder head for forming a valve motion chamber;

a plurality of reed valves for controlling supply of secondary air to the exhaust system; said reed valves being disposed on said head cover;

a cam cap fastened to said cylinder head; and

a valve motion control apparatus disposed in said valve motion chamber;

said valve motion apparatus comprising

a camshaft; and

a main enlarged member extended towards said camshaft, and having a barrier for forming a plurality of reed valve chambers therein; each of said reed valve chambers accommodating respective of one said reed valves therein; said main enlarged member being integrally provided on said head cover at a location at which said reed valves are disposed;

wherein

said cam cap comprises a recessed portion formed thereon; and

said recessed portion in which a portion of the main enlarged member is inserted is provided on the cam cap fastened to said cylinder head so as to cooperate with said cylinder head for rotatably supporting said camshaft.

19. A motorcycle according to claim **18**, where said cam cap further comprises

a pair of bearing portions for sandwiching a plurality of cams provided on said camshaft therebetween, said bearing portion being cooperating with said cylinder head for rotatably supporting said camshaft; and

a connecting portion integrated with said bearing portions for operatively connecting both of said bearing portions to each other;

wherein said recessed portion is provided on said connecting portion.

20. A motorcycle according to claim **18**, wherein said cam cap comprises

a pair of bearing portions cooperating with said cylinder head for rotatably supporting said camshaft; and

a connecting portion integrated with said bearing portions for operatively connecting both of said bearing portions to each other;

an extending portion provided on said connecting portion such that a portion of said main enlarged member is disposed thereon;

wherein said main enlarged member comprises a second enlarged member integrally provided thereon; and wherein said second enlarged member is disposed between said plurality of cams provided on said camshaft, and

said second enlarged member is further extended from said main enlarged member towards said camshaft; and

wherein said recessed portion is provided on said connecting portion.

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